INSTRUMENTS AND CONTROL SYSTEMS

INCLUDING: JOURNAL OF THE SCMA • PRECISION MEASUREMENTS ASSOCIATION • SIMULATION COUNCIL NEWSLETTER

FEBRUARY 1961

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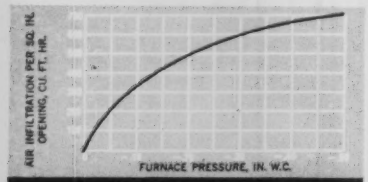
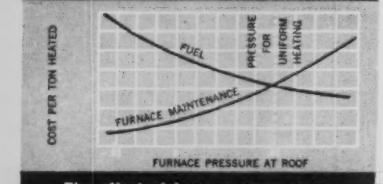
Why **furnace pressure control** should be considered the primary combustion control on heating and melting furnaces



The effect of negative furnace pressure on air infiltration.



The effect of furnace pressure on fuel cost and furnace maintenance.

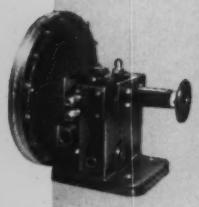
When a negative pressure exists inside a furnace, appreciable quantities of air pass through the walls and openings of the furnace structure. Actual tests have shown that even in an apparently tight furnace the amount of air infiltration can be as high as 40% of the total air required for combustion.

Thus, uncontrolled air infiltration can completely negate the function of accurate fuel-air ratio control. It leads to fuel waste, uneven and irregular heating, excessive cooling of the furnace, and flame impingement on the contents and walls.

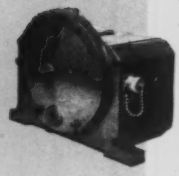
On the other hand, uncontrolled high furnace pressure causes undue heat loss through the furnace walls and openings, the possibility of dangerous blow-outs when doors are opened, and high refractory maintenance cost.

In a properly designed furnace, the furnace pressure that is best for effective heating or melting is also the pressure that provides an optimum relationship between fuel costs and maintenance costs. Precise control of furnace pressure at this one best value is a first necessity for efficient operation.

...and why **GPE Controls** can bring more experience than any other control builder to furnace pressure control applications



GPE Controls Hydraulic Pressure Controller. Thousands of these units are now providing precise pressure control on heating and melting furnaces of all kinds.



GPE Controls Electronic Furnace Pressure Transmitter. Electrohydraulic control system combines advantages of electric transmission and hydraulic operation.

Two generations of heating and melting furnace operators and builders have relied on GPE Controls for furnace pressure control. GPE Controls developed the concepts that made furnace pressure control practical.

The pressure range of a GPE Controls furnace pressure controller is −0.05 to +0.15" w.c. Accuracy of ±1% is equivalent to holding the "zero pressure" level of the furnace within 3" vertically—the degree of accuracy that GPE Controls equipment is designed to provide.

GPE Controls now adds the advantages of electronic transmission to the proved hydraulic control system. The furnace pressure transmitter shown at the left converts the furnace pressure signal to a high-level d.c. voltage signal. Used with GPE Controls electronic controller and electrohydraulic valve actuator, it eliminates long pneumatic signal lines and hydraulic lines. The same furnace pressure signal can operate not only the control but also recorders and indicators. Installation and maintenance are both greatly simplified.

Always be sure to specify GPE Controls furnace pressure control—the primary combustion control.

Write for descriptive literature

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A Subsidiary of GENERAL PRECISION, Inc.

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Choose from 30 standard scale ranges.

Hand drawn Scales, eight inches long for easy readability.
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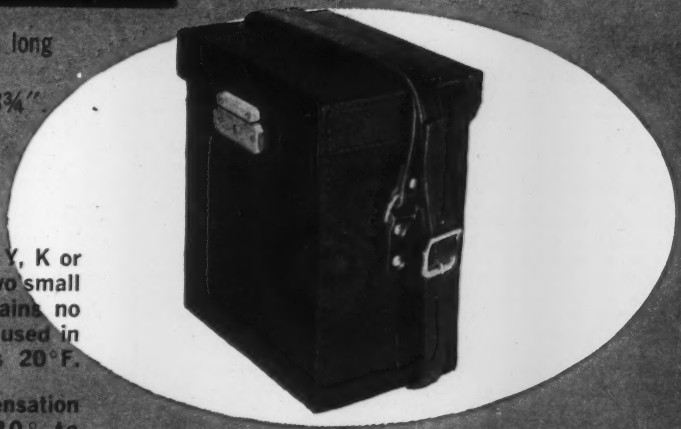

Calibrated for use with Type J, Y, K or T thermocouples. Operated by two small flashlight cells, the 73PO contains no standard cell to freeze, can be used in temperatures as low as minus 20°F.

Electrical cold junction compensation insures accuracy from —20° to +120°F. ambient temperatures.

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Specialists in Electrical Temperature Measurements
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CIRCLE 2 ON READER-SERVICE CARD

NEW! SENSITIVE RESEARCH "COMMANDER" INSTRUMENTS

LOW THERMAL CHOPPERS

The Types 9742, 9743, and 9744 Low Thermal Choppers have resulted from design work accomplished at the National Research Council in Ottawa, Canada. Their construction makes them particularly adaptable to circuits where thermal noise is of importance, such as in low level DC amplifier applications and Hall Effect measurements.

SPECIFICATIONS

THERMAL EMFs: *0.02 μv or less.*

CONSTRUCTION: Contain 2 (Type 9742), 3 (Type 9743), or 4 (Type 9744) DPDT switches, all actuated by a common shaft. Switch arms are made of copper. Contacts are solid gold blocks. Switch sections are separated by electrostatic screens and surrounded by heavy metal covers to maintain thermal equilibrium. The Type 9743 is particularly adaptable for OEM applications because of its small size (3½" x 5¼" x 4" high).

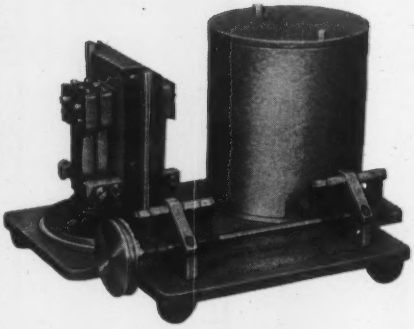
RELATIVE PHASE OF SWITCHES: Adjustable through 360° by rotating the cams on the shaft.

MAKE/BREAK RATIO: Each contact can be separately adjusted from 0 to 100% of a cycle with an accuracy of ±1%.

CURRENT CAPACITY: Depends whether circuit is resistive, capacitative or inductive. Will usually operate in purely resistive circuits to interrupt up to 100 millivolt amperes. Correspondence necessary for special applications.

CHOPPING FREQUENCIES: Speeds up to 60 cps. are normal. Optimum speed depends on applications, i.e. in a DC amplifier operating from a 60 cycle supply, a maximum rejection of 60 cycle pick-up can be obtained at a speed of approximately 37.5 cps. Speeds up to 90 cps. can be used by increasing the tension of the spring on the rod return.

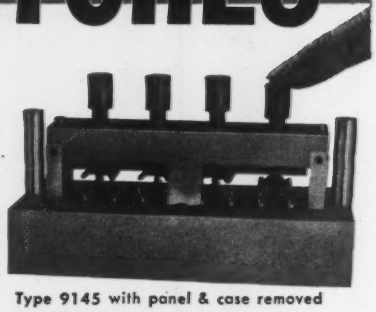
DRIVING MECHANISM: A small synchronous motor capable of a 0.8 inch-oz. torque. (Not furnished)



Type 9744
with one cylinder removed

LOW THERMAL SWITCHES

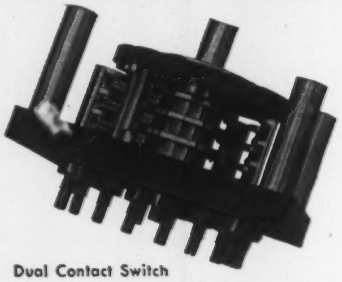
The Type 9145 Low Thermal Selector Switch is intended for use in potentiometer or other circuits where the generation of stray emfs must be kept to an absolute minimum. Its construction (based upon an ingenious design by Dr. T. M. Dauphinee of the National Research Council in Canada) assures a positive circuit connection by the use of self-wiping contacts while the generation of thermal emfs under all possible conditions is limited to less than 0.01 μv. The switch contains 4 DPST sections with all tellurium-copper contacts and is mounted in a solid block of aluminum to minimize temperature gradients. Operation is made simple by allowing for the selection of any one of 4 circuits by merely depressing a push button. The buttons lock down automatically and release when any other button is depressed. Two or more buttons may be simultaneously depressed if desired. A separate release button is provided to open all circuits. The terminals can be cross connected for applications requiring a reversing switch.



Type 9145 with panel & case removed

Dual Contact Switches. A wide variety of standard and special self-cleaning dual contact switches are available for transfer and/or reversing applications demanding the highest degree of precision and reliability.

The complete wiper or brush is made up of two assemblies, each with 8 individually sprung contact arms that are separated and riveted together at the center. The elasticity of the wiper arms maintains the whole assembly against the inner surfaces of the center segments of the brush and the stationary contacts. This arrangement effectively allows the wiper to "float" between the stationary contacts since it is not mechanically held in place other than by the pressure of its own individually sprung arms. Hence, contact pressure and contact resistance is always constant. All copper contacts are used when low resistance or thermoelectric free switches are required. The generation of thermal emfs can be kept as low as .01 μv. For exceptionally low resistance applications, the wiper assemblies can be paralleled. Switches with copper contacts have a resistance as low as 100 microhms between soldering points and will vary less than 10 microhms between contact points.



Dual Contact Switch

The Type 9600 Low Thermal Reversing Switch with oil immersed all copper contacts simplifies and speeds up the operation of precision potentiometers. By a single turn of the switch the potentiometer battery and two measuring circuits are reversed and the galvanometer is disconnected during the change over. If only one measuring circuit is in use the spare section of the switch can be utilized to reverse the standard cell and thus make it possible to check the standardization of the potentiometer with either a + or − connection of the battery. In the battery circuit the switch contacts do not introduce a change in resistance large enough to significantly affect the potentiometer current. The maximum change of contact resistance on reversal does not exceed 100 μΩ. In a typical potentiometer of 100 Ω resistance this would cause a change in current of 1 ppm.

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INSTRUMENTS AND CONTROL SYSTEMS

Pressure measurement is the subject for major emphasis this month.

VOLUME 34, NUMBER 2, FEBRUARY 1961

PRINT ORDER THIS MONTH 42,200

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1960 Computer Progress 229
Covers new computers, applications, trends in system organization, computer control, medical implications and new techniques.

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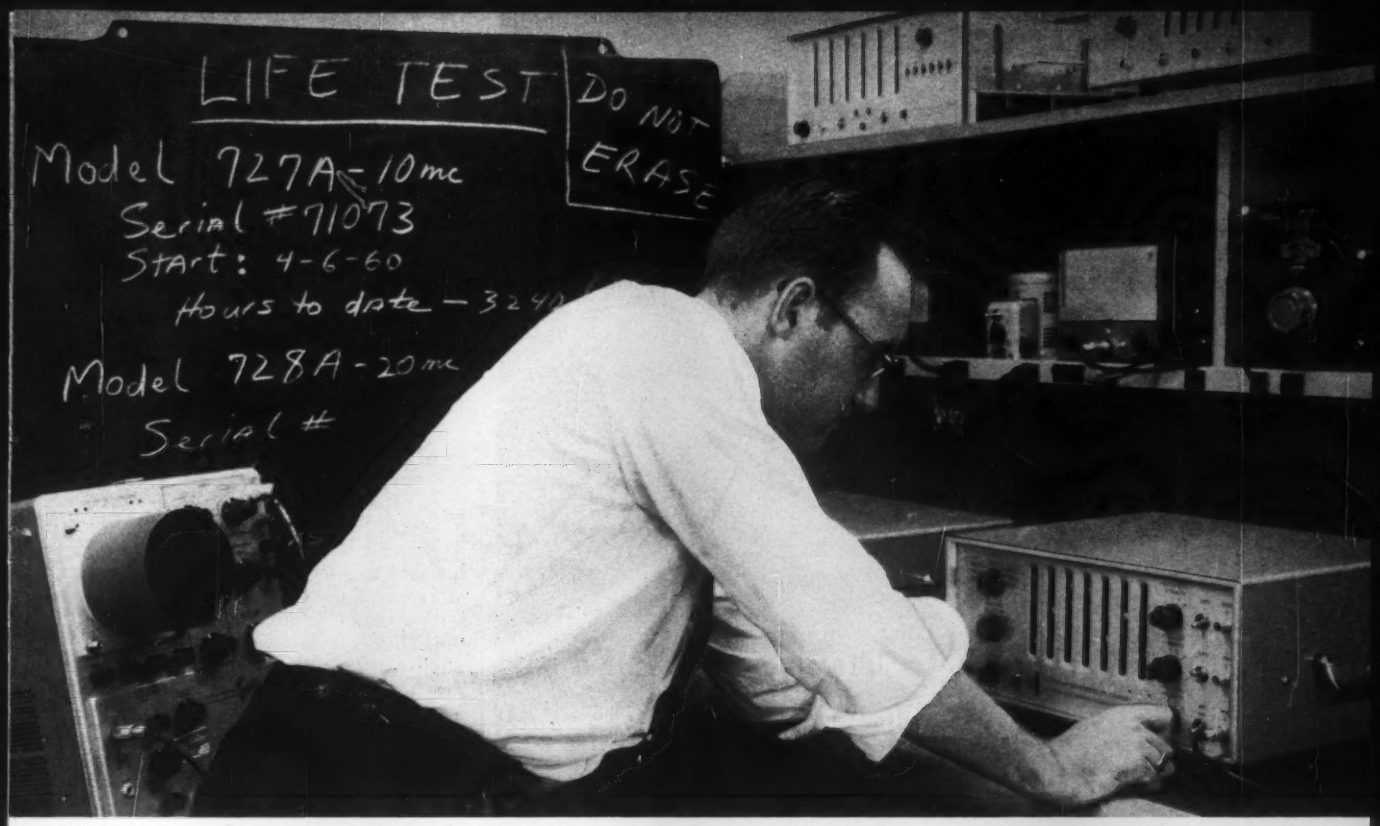

How long will you keep buying obsolete counters

when CMC counters with solid state reliability cost so little more?

Announcing the CMC 728A

A SOLID STATE 20 MC UNIVERSAL COUNTER-TIMER

Introduction of the CMC 728A marks another frequency step-up from the company that brought you the first transistorized universal counter-timers. CMC, the leader in truly advanced counting, timing, and frequency measuring equipment offers 100 kc, 250 kc, 1 mc, 10 mc and now 20 mc all solid state instrumentation.

	Most Popular 10 mc Vacuum Tube Counter	CMC Solid State 10 mc Counter
Base Price	$2,300	$2,750
Printer Output	75	n/c
Time Interval Section	175	n/c
Total	$2,550	$2,750
Weight	118 lbs.	27 lbs.
Size	21⅛"H x 20"W x 23½"D	7"H x 17"W x 13"D
Power Requirements	600 watts	46 watts
Accuracy	± 1 count ± crystal stability	± 1 count ± crystal stability
Remote Programming	not available	Standard option
Warranty	1 year	2 years
Time Interval Measurements	1 μsec to 10^7 sec in 1 μsec increments	0.1 μsec to 10^7 sec in 0.1 μsec increments
Period Measurement	0 cps to 10 kc	0 cps to 3 mc
Gate Times	0.001, 0.01, 0.1, 1.0 & 10 sec	0.000001 to 10 sec in decade steps
Time Base	10 to 1 multivibrator type	decade dividers — no adjustment

Can You Afford To Settle For Less? If you are considering any counter, will your engineering judgement and sense of *real* economy dictate purchase of old fashioned equipment? Stop and look at the merits of solid state counters. Did you know that the reliability of all CMC solid state counters is backed with a 2 year warranty—double the guarantee of tube counters? Did you know CMC's solid state 10 mc universal counter timer only costs $200 more than comparable vacuum tube counters? That's the beginning. Compare the rest of these specifications.

Compare the 20 mc Solid State Universal Counter-Timer—We'd like to, but frankly, there aren't any comparable vacuum tube counters. This might lead the discerning engineer to think that at 10 mc, vacuum tubes are driven "hard", right to their capacity. *And he'd be right.*

More Information—For complete technical information on high reliability solid state counting instrumentation, call your nearby CMC engineering representative, offices in 33 cities throughout the U.S. and Canada, or write directly to Dept. 552.

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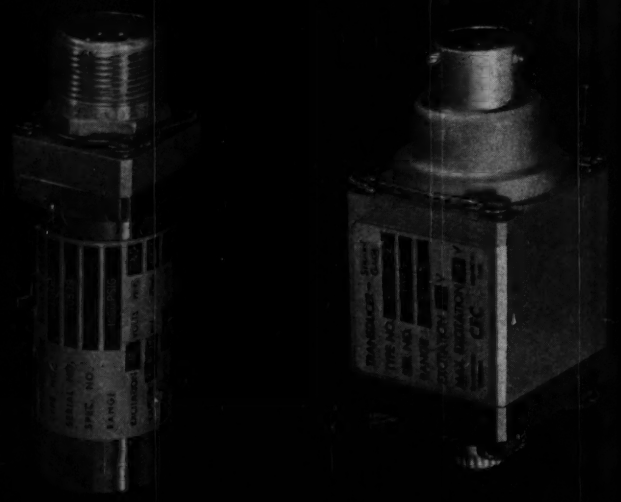

High range . . . low range–

BOTH OF THESE NEW CEC PRESSURE TRANSDUCERS FEATURE BUILT-IN SHUNT COMPENSATION

These new strain gage units are the most accurate and highly sophisticated pressure transducers ever built for rugged airborne use. They were designed to outperform every known similar type of instrument . . . and they do.

Their shunt calibration feature permits the system designer to provide—quickly and simply—a complete calibration of his data handling system for precise control of associated equipment.

Type 4-328 (square) is a low-range unit for pressure ranges of 0-15 psi through 0-99 psi absolute. Standard ranges are 0-15, 20, 30, 50 and 75 psi absolute. **Type 4-329** (tubular) is a high-range unit for pressure ranges of 0-100 psi through 0-5000 psi absolute. Standard ranges are 0-100, 150, 250, 500, 1000, 1500, 2500 and 5000 psi absolute.

Here are some of the specifications they have in common:

Rated electrical excitation: 20v dc or ac rms; carrier frequency 0-20 kc.

Sensitivity: 50 mv ±0.25 mv into a 50k load at rated excitation and 77°F.

Compensated temperature range: +30°F. to +250°F.

Weight: 5.5 oz. max. exclusive of mating electrical connector.

Input impedance: 700 ohms minimum.

Output impedance: 350 ohms ±10% at 77°F.

Shunt output: 33,270 ohms keyed across negative input and negative output pins at zero applied pressure, rated excitation, and 77°F., produces an electrical output change equal to the sensitivity within a tolerance of ±0.355%.

For more information and complete specifications, call your nearest CEC sales and service office or write for Bulletin CEC 4328-X1 or 4329-X1.

Transducer Division CEC

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I&CS LETTERS TO THE EDITOR

Editor, I&CS:

The article by Ross E. Hupp, titled "Frequency Counter" was most enlightening. Although the particular unit he describes is not incorporated in APCHE (Automatic Programmed Checkout Equipment), which was built by RCA for Convair-Astronautics, the technique described is applicable. The counters in that equipment have both add and subtract capability. It is regrettable that more of the automated checkout equipment now being designed does not take this technique into consideration. In many cases, redundancy of testing could be eliminated. Iterated tests become necessary when only additive capability is designed into the test equippment, in order to achieve the level of accuracy required.

Although I only recently subscribed to your publication, I am finding its contents more valuable than most of the other technical publications I receive put together. Articles are not only informative, from an academic standpoint, but are in many cases directly applicable to tasks on hand. Speaking of applicable articles, if you have any plans for making the series on Symbolic Logic available in reprint form, please put me down for a copy.

Meyer Cook
Senior Electronics Engineer
Nortronics Division
Northrop Corp.
Santa Monica, Calif.

The symbolic-logic series will be available in about six more months, at its conclusion.

Editor, I&CS:

Received my copy of *ELECTRONIC CIRCUITRY*. This book can be used as a valuable text for an adult education course. Can you make available 35MM film slides of your figures and tables to be used for classroom instruction?

George J. Sladick
Hicksville, N. Y.

The ELECTRONIC CIRCUITRY book is being used in many adult education courses, especially by instrument manufacturers who give courses in electronics to their field salesmen. It also is being used in high-school work. Sorry, we do not have any slides available.

← CIRCLE 5 ON READER-SERVICE CARD

Editor, I&CS:

You have been probably informed that great efforts have been made in our country in the endeavor to equip industries with up-to-date equipment, particularly in respect of regulation and measuring devices. Here, in the first line, we must collect detailed knowledge about the modern development achieved hitherto in other countries.

Our organization has set itself the task to study the theoretical and practical aspects in regulation and measuring techniques. In the course of our activities we have already organized two Seminars to this purpose. In these Seminars, besides Yugoslav lecturers, some twenty-two foreign lecturers, coming from seven countries have given their lectures on the mentioned themes. These lectures were attended by 240 Yugoslav technical experts, belonging to some 73 industrial enterprises pertaining to all branches of industry.

"Jurema"
Jugoslavenski Seminar za Regulacyu
Mjerenje I Automacyu
zagreb-Fabkoviceva ul. 1
Yugoslavia

Editor, I&CS:

This ripped and torn envelope returned by the post office is the reason for my delay in payment for my *I&CS* subscription. Dog attacked mail man.

David Limbacher
Rocketdyne
Boron, Calif.

Myograph

Director of medical clinic seeks manufacturer of Myograph which records action current of muscles. A-6107

Solenoids

Vice president of research lab seeks source of ultra-slim (1" dia) solenoids working on 6 vdc having as strong a pull as possible. A-6108

Three-dimensional Display

Engineer with British aircraft manufacturer seeks any form of a three-dimensional display using CRT, etc., and complementary power transistors with V_{ce} = 100 v and minimum I_c = 1 to 2 amp. A-6109

Sprocket Chain

Research assistant in university aeronautical research lab seeks miniature bicycle-type chain similar to that used in dial indicating barometers. A-6110

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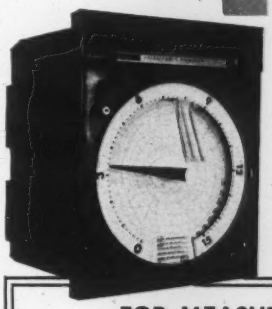
NEW



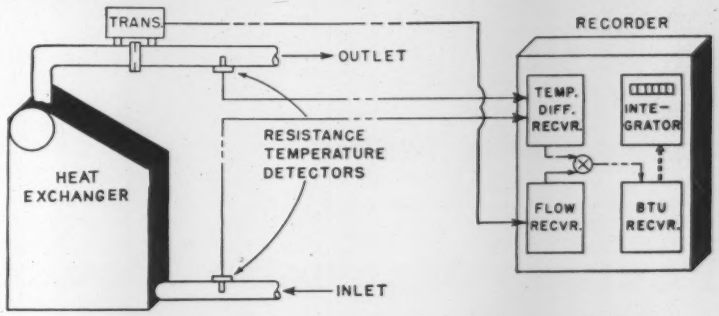
HAYS BTU METER

FOR MEASUREMENT OF HEAT TRANSFER IN

- Hot water boilers
- Refrigerating systems
- Cooling towers
- Chemical processing
- Power applications

Now a single recorder can provide data on BTU, flow, and differential temperature, plus BTU totalization. This new unit incorporates components proven in hundreds of applications. Its operation is indicated in the diagram below.

The temperature of the liquid as it enters the heat exchanger is measured by a platinum resistance temperature element. Another similar element measures liquid temperature leaving the exchanger. A Hays model 245 flow transmitter measures liquid flow through the process. These variables are recorded, retransmitted and multiplied. The product is then transmitted to a BTU receiver which records rate of BTU gain or loss, and to an integrator totalizing BTU's gained or lost.



The features of the new Hays BTU Meter include:

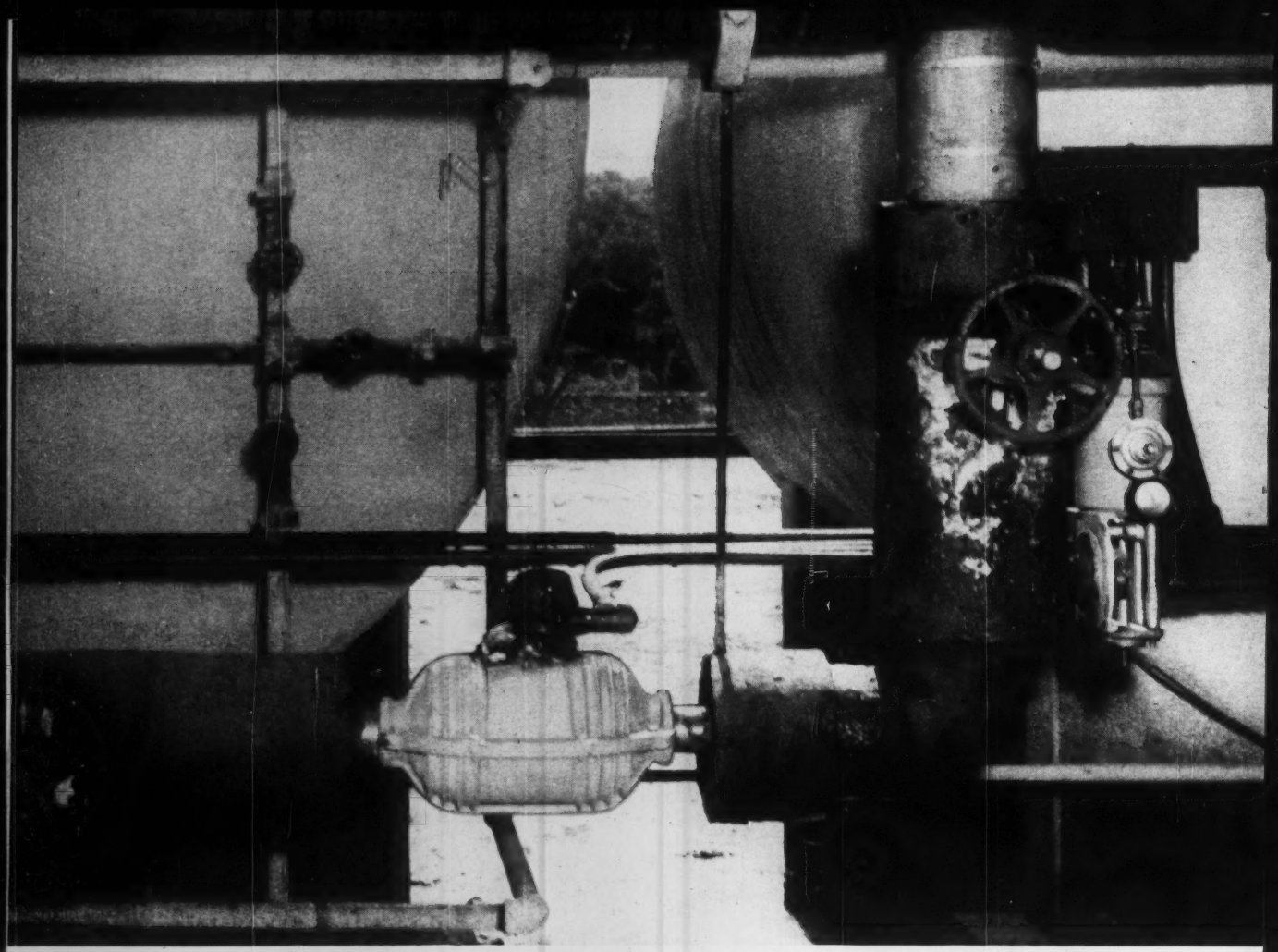
- Only one unit for recording BTU, differential temperature, fluid flow and totalizing BTU
- Increased accuracy. No loss by transmission between recorders.
  Accuracy specifications include:
  Differential temperature: within ± 0.5% chart calibration
  Flow: within ± 0.25 maximum transmitter differential
  BTU Record: slightly over 1% over entire range of Delta T at 70% to 100% of fluid flow
- Easy to install
- Accurate and easy checking of BTU record
- Easy to service. All components readily accessible
- Fast response due to electronic rebalancing of three transmitted signals
- Narrow differential temperature ranges available for maximum accuracy and sensitivity
- Switches can be added for alarm or safety purposes

Model 913 BTU Meters can be adapted to any 20° F minimum to 180° F maximum fluid temperature differential span on operating temperatures of from 32° F to 500° F for the stated accuracies. Greater temperature difference spans can be handled with corresponding change in accuracies. Standard models have been developed for chilled or hot water. Modifications permit use with other fluids.

A new bulletin, 58-B913, contains complete information of the new Hays BTU meter. Write for your copy today.

THE hays CORPORATION
MICHIGAN CITY, INDIANA

CIRCLE 6 ON READER-SERVICE CARD



One of six Foxboro Magnetic Meters at International Salt Company's Avery Island Refinery. Meters are measuring 220°F sodium chloride brine being discharged from filters on International's Recrystallizer Process.

Foxboro Magnetic Flow Meters handle 220°F salt brine just like water!

Foxboro Dynalog Instrument indicates flow rate through any one of the 6 Magnetic Meters — at the flip of a switch.

"trouble-free" – International Salt reports

220°F — that's the temperature of sodium chloride brine as it leaves filters at International Salt Company's Avery Island Refinery in Louisiana. And their 6 Foxboro Magnetic Meters have been providing continuous, trouble-free flow measurement of this highly corrosive liquid for over a year.

These meters easily handle this punishing chemical. They're lined with corrosion-proof Kel-F — have no flow restrictions of any type. Linear measurement — accurate to ±1% across the entire scale — is indicated on remote Foxboro Dynalog* instruments.

Since its introduction 5 years ago, the Foxboro Magnetic Meter has simplified the measurement of difficult liquids in hundreds of industrial processes. Ask your nearby Foxboro Field Engineer how it can help your process. Or write for Bulletin 20-14. The Foxboro Company, 462 Neponset Avenue, Foxboro, Massachusetts.

Reg. U.S. Pat. Off.

FOXBORO
REG. U.S. PAT. OFF.

CIRCLE 7 ON READER-SERVICE CARD

HALF the world is half asleep! Men who could be making *twice* their present salaries are coasting along, hoping for promotions but doing nothing to bring themselves forcefully to the attention of management.

They're *wasting* the most fruitful years of their business lives . . . throwing away thousands of dollars they may never be able to make up. And, oddly enough, they don't realize—even remotely—the tragic consequences of their failure to forge ahead while time is still on their side.

Engineers and other technically-trained men are particularly prone to "drift with the tide" because their starting salaries are reasonably high and promotions come at regular intervals early in their careers. It isn't until later—too much later in many cases—that they discover there is a definite ceiling on their incomes as technicians.

Send for Your Free Copy of "Forging Ahead in Business"

If you want to discover how to succeed while you are still young—if you want to avoid the heartbreak of failure in later years—send today for "*Forging Ahead in Business*" . . . one of the most practical and realistic booklets ever written on the problems of personal advancement.

Here you will find—not a "pep-talk," not an academic lecture—but cold, hard *facts* on how to improve your position and increase your income. You will be told what the qualifications of an executive are in today's competitive market . . . what you must *know* to make $15,000, $20,000 or more a year . . . what you must *do* to accumulate this knowledge.

"Forging Ahead in Business" was written for mature, ambitious men who seriously want to get down to bed-rock in their thinking about their business future. If you feel it is meant for you, simply fill in and return this coupon. Your complimentary copy will be mailed to you promptly.

Mail Coupon Now!

ALEXANDER HAMILTON INSTITUTE
Dept. 299 71 W. 23rd Street, New York 10, N. Y.
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Please Mail Me, Without Cost, a Copy of Your 48-Page Book—
"FORGING AHEAD IN BUSINESS"

Name.....

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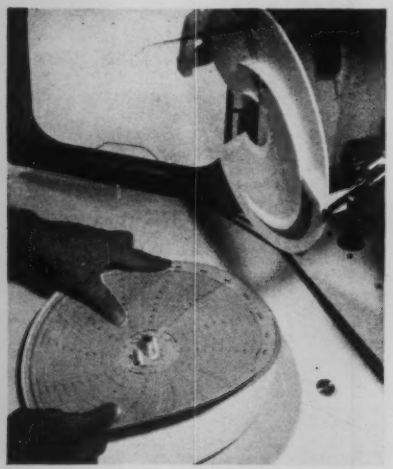
CIRCLE 8 ON READER-SERVICE CARD

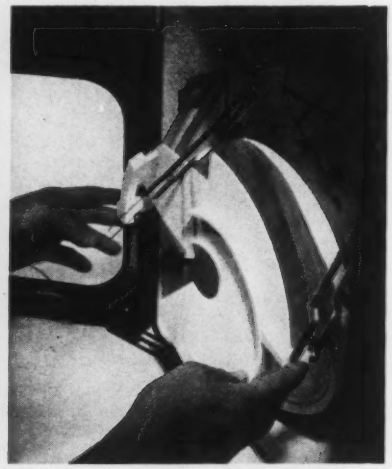
ANNOUNCING THE BARTON AUTOMATIC CHART CHANGER

LOADING IS SIMPLE...



1. The Barton chart changer will hold up to 16 patented, split charts. A locating pin on the chart plate makes it virtually impossible to load incorrectly.

2. With the scroll assembly and the pens mechanically lifted and locked out of the way, the loaded chart plate is quickly mounted onto the chart drive shaft.



3. The scroll assembly and pens are lowered and locked into place. There is nothing to adjust, nothing to go wrong. Capillary pens are supplied by ink bottle inside the case.

CIRCLE 9 ON READER-SERVICE CARD

HANDLES UP TO 16 CHARTS; AUTOMATICALLY CHANGES TO A NEW CHART ON EACH REVOLUTION OF THE CHART DRIVE

Now your recorders can operate for up to 16 days, *untended*, and still produce a separate 24 hour chart for each day. The amazing new Barton chart changer eliminates the need for manual chart changing; it does the job *automatically* and *by itself!* Simple and foolproof both in handling and operation, the Barton chart changer *simplifies your accounting* by providing exact, consistent accounting periods, *cuts down your labor costs* by drastically reducing the frequency of your chart routes, *increases the readability of your records* by making it possible to select the optimum chart rotation for each application. Available in complete, ready-to-install kit form (it fits the Barton 202 and 202A recorders, the Bristol series 500 case, and the American Types D and A cases) the Barton chart changer will not jam, miss charts, or allow the recorded charts to be damaged. It is completely dependable, as reliable as the recorder. For complete information, see your Barton man or send in the coupon today.

Gentlemen: Please send me your free bulletin on the new Barton Chart Changer.

NAME _____

COMPANY _____

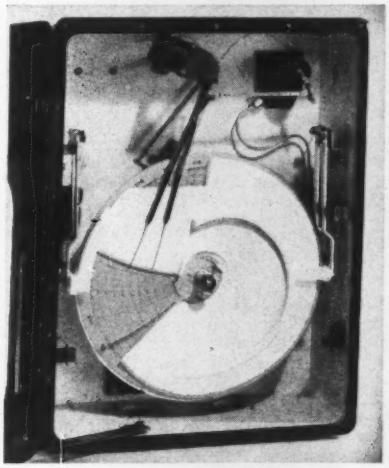
ADDRESS _____

CITY _____ ZONE _____ STATE _____

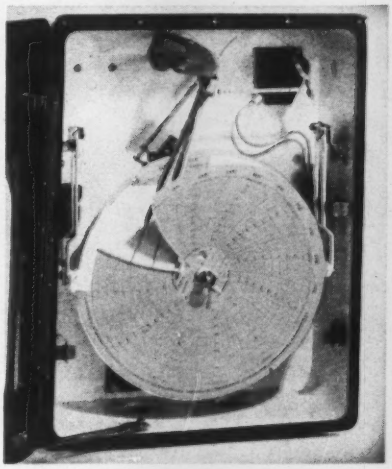
BARTON® INSTRUMENT CORPORATION

580 MONTEREY PASS ROAD • MONTEREY PARK, CALIFORNIA

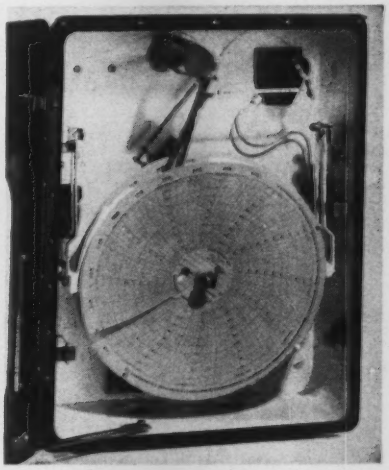
OPERATION IS SURE!



1. With the chart changer in position, the recorder is ready to operate. A portion of the chart (in green for illustration) shows from behind the scroll. Note the tab on the chart has just been picked up by the scroll knife edge.

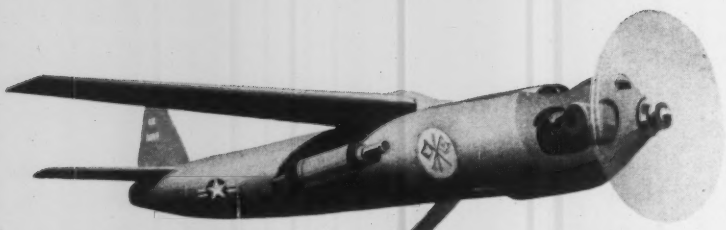


2. As the chart drive rotates, the portion of the chart that has been recorded is spun onto the shaft and well away from the pens which are now recording on the last part of the chart.

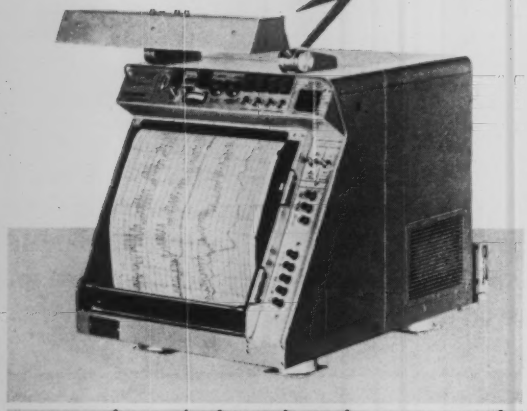


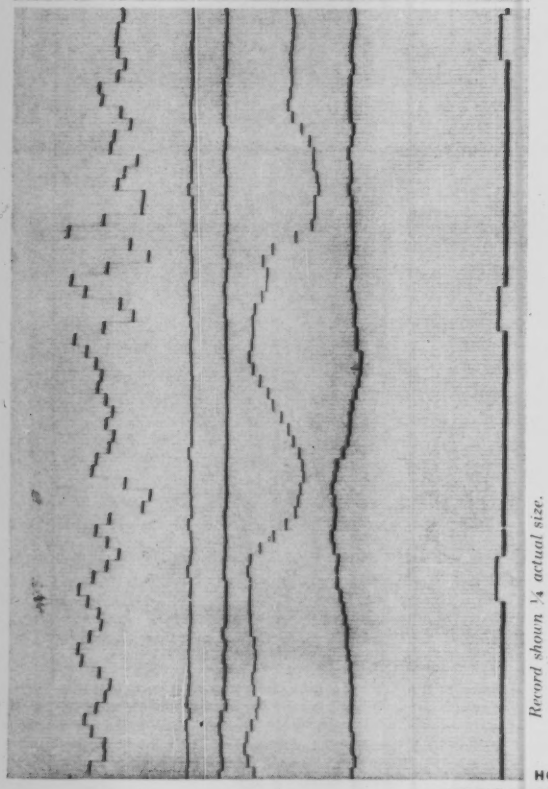
3. The first chart has now completed its cycle and is held for storage on the shaft, clear of the pens, which are now recording on the newly exposed second chart. The pens begin recording on the new chart at the precise moment the first chart completes its rotation.

CIRCLE 9 ON READER-SERVICE CARD



Tracking a Surveillance Drone with the Visicorder





Record shown ¼ actual size.

Drone surveillance and reconnaissance gives U.S. Army combat units a high-altitude vantage point with much broader horizons from which to view battlefield action and terrain.

If effective use of the data gathered by the drone—the "eye in the sky"—is to be made, accurate instruments have to be on hand to monitor the drone's position and movement, its operational behavior and its response to flight commands. Telemetry supplies the radio link which transmits all this behavior information to a thoroughly-instrumented mobile tactical command post developed by Tele-Dynamics Division of American Bosch Arma Corp.

The Honeywell Model 1012 Visicorder has been selected as the direct readout unit in the Tele-Dynamics Drone Surveillance Telemetry system. In use with its companion instrumentation, the 36-channel Visicorder simultaneously displays the 22 channels of information required to track a drone, plus the timing traces.

In the Tele-Dynamics van, which serves as a tactical command post, the Visicorder provides both an instant "quick look" and a permanent record of the drone's operational parameters.

Signals are transmitted over a single channel by time-multiplexing. Signal and battery strength, engine speed and temperature, pitch and roll commands, altitude, airspeed, attitude (pitch and roll), yaw, acceleration (horizontal and vertical), and angle of attack are recorded by the Visicorder, along with three separate records of vibration.

Like the other units of the Tele-Dynamics system, these Honeywell Visicorders are built for rugged service . . . to deliver the data . . . when the drone is up and the chips are down.

Call your nearest Minneapolis-Honeywell Industrial Sales Office for a demonstration of how a Visicorder Oscillograph will save you time and money in data acquisition. OEM inquiries invited.

Reference Data: write for bulletins 906, 1012, 1108 and 1406.

Minneapolis-Honeywell Regulator Co.
Industrial Products Group, Heiland Division
5200 E. Evans Avenue, Denver 22, Colorado

Honeywell

Industrial Products Group

HONEYWELL INTERNATIONAL *Sales and Service offices in all principal cities of the world.*

CIRCLE 10 ON READER-SERVICE CARD

PORTABLE PROTECTION

FOR *Precision* EQUIPMENT

Skydyne Molded Fiberglass hand-portable transit cases, with precision engineered interior cushioning and mounting hardware, provide maximum protection for delicate instruments and equipment.

HIGH RESISTANCE TO IMPACT, CHEMICALS, MOISTURE, CORROSION AND WEATHER.

HARD, MAR-RESISTANT, EASY-TO-CLEAN SURFACE.

MOLDED-IN COLORS. NO ADDITIONAL FINISHING REQUIRED.

LIGHT WEIGHT — GREATER STRENGTH, POUND FOR POUND, THAN OTHER MATERIALS.

IN-PLANT HANDLING CAUSES NO DENTING OR DISTORTION.

Available in 22 standard sizes, to meet MIL-T-945A and MIL-STD-108C specifications. Modifications provide a wide range of sizes for custom requirements.

Internal fittings can include brackets for mounting modular instrument panels.

INSTRUMENT CASE DESIGNED AND BUILT FOR LEAR, INC.

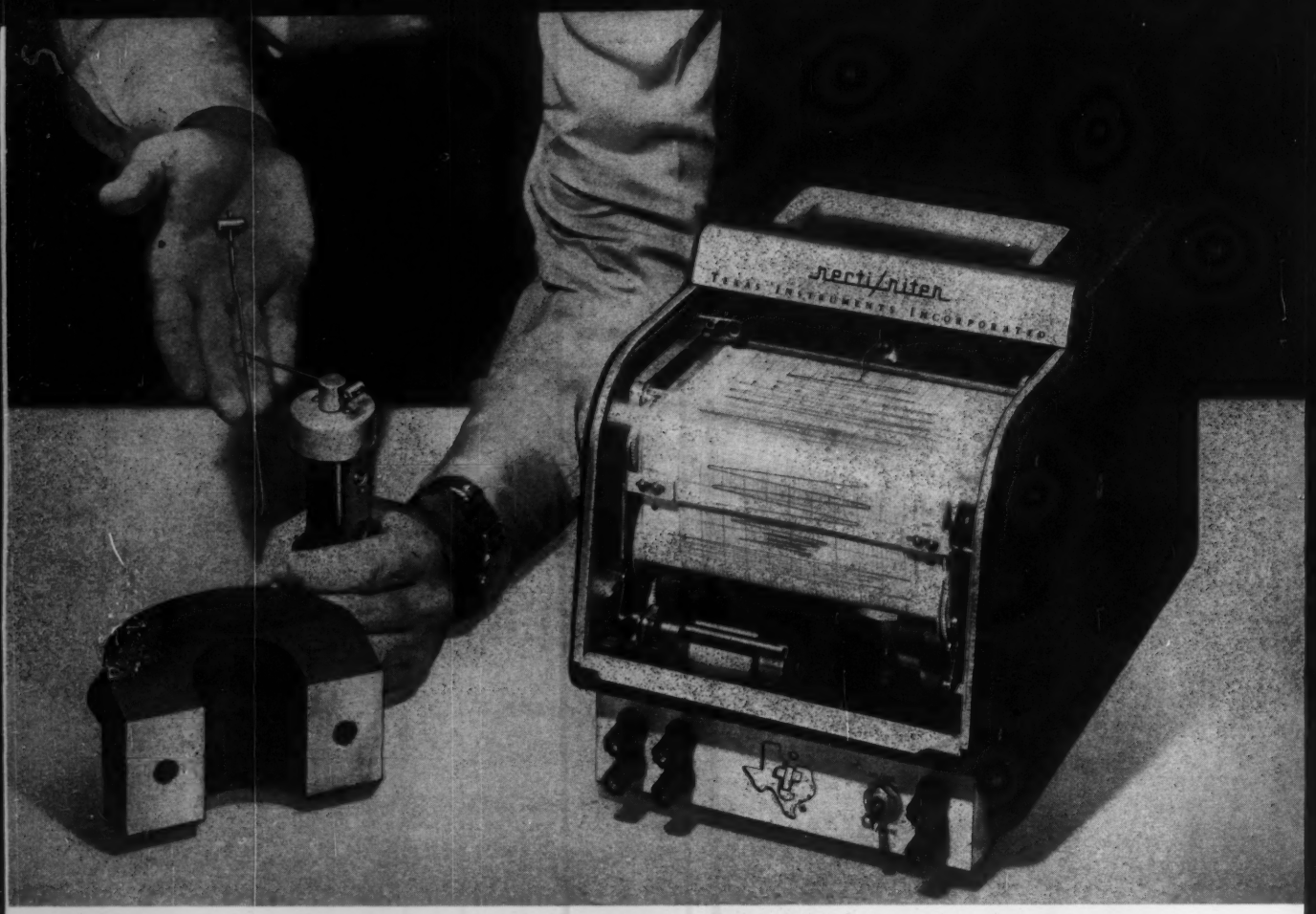
MINIMUM WEIGHT ★ Skydyne, Inc MAXIMUM STRENGTH

Skydyne, Inc

RIVER ROAD PORT JERVIS, NEW YORK

SKYDYNE FIBERGLASS TRANSIT CASES—STANDARD CASES FOR CUSTOM EQUIPMENT.

CIRCLE 11 ON READER-SERVICE CARD



recti/riter® recorders prove what every engineer knows . . . SIMPLICITY MEANS RELIABILITY

What simpler and more reliable actuating device can you employ in an amperage-voltage-frequency recording instrument than a d'Arsonval galvanometer . . . a trouble-free horseshoe magnet and a coil of wire? The same is true of the exclusive "recti/rite"® system . . . a simple, shock resistant trigonometric linkage that straightens the arc described by the galvanometer metering arm, changing curvilinear motion to rectilinear motion.

All the other "recti/riter" recorder features which contribute to this instrument's multi-industry acceptance and hardworking reliability are equally simple: The optional a-c or d-c drives couple directly with chart speed change gears to allow ten chart speeds; all routine operations and adjustments are performed "up front"; the non-corrosive, honed metal alloy pens, closed ink system, and large capacity ink well give you long, consistent writing performance.

With all their simplicity and reliability, "recti/riter" recorders are offered in extremely wide and useful Basic Recorder Ranges (Dual channel recorders offer combination of any two ranges):

Two Cycle Pen Response

D-c Milliampere Ranges ..... ¼ ma to 100 ma
A-c Ampere Ranges ..... 0.25 A to 25 A
D-c Ampere Range ..100 mv for use with standard shunts
Expanded Scale A-c Voltage Ranges ..... 80-130 V, 160-260 V, 320-520 V
A-c and D-c Voltage Ranges ..... 10 V to 1000 V
Frequency Ranges ..... 50, 60, 400 cps

Five Cycle Pen Response

D-c Milliampere Range ..... 5 ma

Ask the TI engineer about *customized* recorders for your OEM applications. Don't settle for any recorder until you know all the facts on the complete "recti/riter" recorder line.

TEXAS INSTRUMENTS
INCORPORATED
GEOSCIENCES & INSTRUMENTATION DIVISION
3609 BUFFALO SPEEDWAY • HOUSTON 6, TEXAS • CABLE: TEXINS

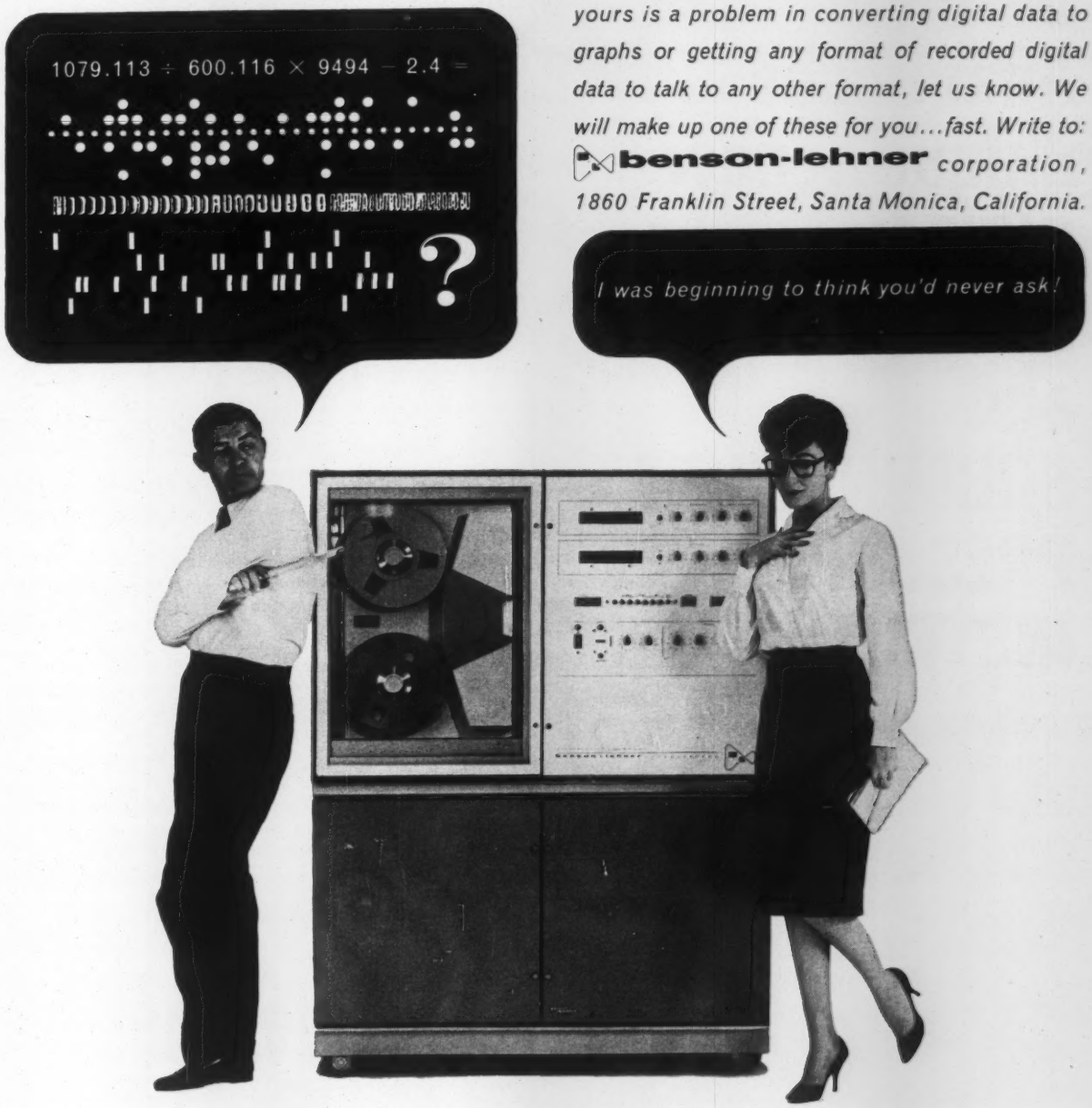
The proved "recti/riter" recorder is a companion to the new "servo/riter"* recorder.

*"servo/riter" is a trademark of Texas Instruments

CIRCLE 12 ON READER-SERVICE CARD

Nothing is lost in the translation with Benson-Lehner's new Machine Language Translator. What is gained, however, with this new solid-state instrument is the ability to translate machine languages. The Translator will automatically convert data in one digital code or form to, 1) output in another digital code or form, or 2) to a signal suitable for input into any Benson-Lehner Electroplotter or similar device. Translation speeds are dictated by the input and/or output modes, i.e., operating speed in conversion of digital magnetic tape to graphs is limited by the speed of the graphing instrument. If yours is a problem in converting digital data to graphs or getting any format of recorded digital data to talk to any other format, let us know. We will make up one of these for you... fast. Write to:

benson-lehner *corporation, 1860 Franklin Street, Santa Monica, California.*



CIRCLE 13 ON READER-SERVICE CARD

DeJUR Announces unique... new DIGITAL TRANSDUCERS and SUBMINIATURE PRESSURE INSTRUMENTS

DeJur Digital Transducers are self-contained solid state miniaturized packages designed to measure various parameters (pressure, temperature, flow, acceleration) and supply a digital signal output without the use of auxiliary equipment. The result can be a pulse duration type (PDM) digital signal whose pulse width in time is directly proportional to the amplitude of the input parameter being measured. PPM and PFM outputs also can be made available.

Constructed to meet rigorous conditions of application and exposure, DeJur Digital Transducers produce signals compatible with digital computers and electronic counters found in all military and industrial installations.

A new dimension in pressure instrumentation is created by the introduction of a complete line of subminiature pressure instruments. It includes potentiometric pressure transducers, pressure switches and pressure indicating meters with static, dynamic and environmental performance characteristics superior to larger units.

FEATURES

- **Small size . . . light weight**
- **Completely self-contained—no auxiliary conversion equipment needed**
- **Accuracy equal to much larger units**
- **Improved environmental and dynamic performance—ideal for military applications**
- **Multiple outputs obtainable**
- **Superior reliability and versatility**

WRITE FOR DETAILED INFORMATION

You're always sure with **DeJUR**
ELECTRONIC COMPONENTS

ELECTRONICS DIVISION, DeJUR-AMSCO CORPORATION, 45-01 NORTHERN BLVD., LONG ISLAND CITY 1, N. Y.

SEE THEM AT DeJUR BOOTHS 2307-2309, I.R.E. SHOW

CIRCLE 57 ON READER-SERVICE CARD

jamesbury "Double-Seal" BALL VALVES*

TM

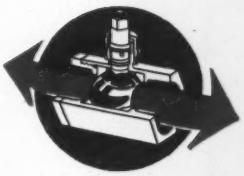
*PATENTED

AS VERSATILE AS INDUSTRY ITSELF

The illustration below gives you a glimpse of the depth of application of the versatile Jamesbury "Double-Seal" Ball Valve.

For on-off, quarter turn, full flow, leakproof, maintenance-free operation, no valve can match the exclusive Jamesbury "Double-Seal" action.

We will welcome an opportunity to prove this statement, whatever your valving requirements might be.



JAMESBURY CORP., 78 NEW STREET, WORCESTER, MASS.

DISTRIBUTORS IN PRINCIPAL CITIES

© 1961 Jamesbury Corp. 103-0

1. Standard flange with PC 50 operator.
2. Screwed end type
3. 6" flange with ST 490 operator
4. 6" flange for manual operation
5. PVC screwed end type
6. Screwed end with EM 25
7. Screwed end with PC 50 operator
8. 2" flanged valve
9. PVC flanged valve

MATERIALS:

Jamesbury "Double-Seal" Ball Valves are available in Types 303, 316 and Alloy 20 Stainless Steels, Carbon Steel, Bronze, Ductile Iron, Monel, Aluminum and PVC. Other materials on special order.

Interchangeable seats and seals are available in "Teflon", Nylon, Buna-N, Neoprene, Hypalon and natural rubbers.

Pneumatic, Hydraulic and Electric Motor Operators to fit Remote Control Requirements.

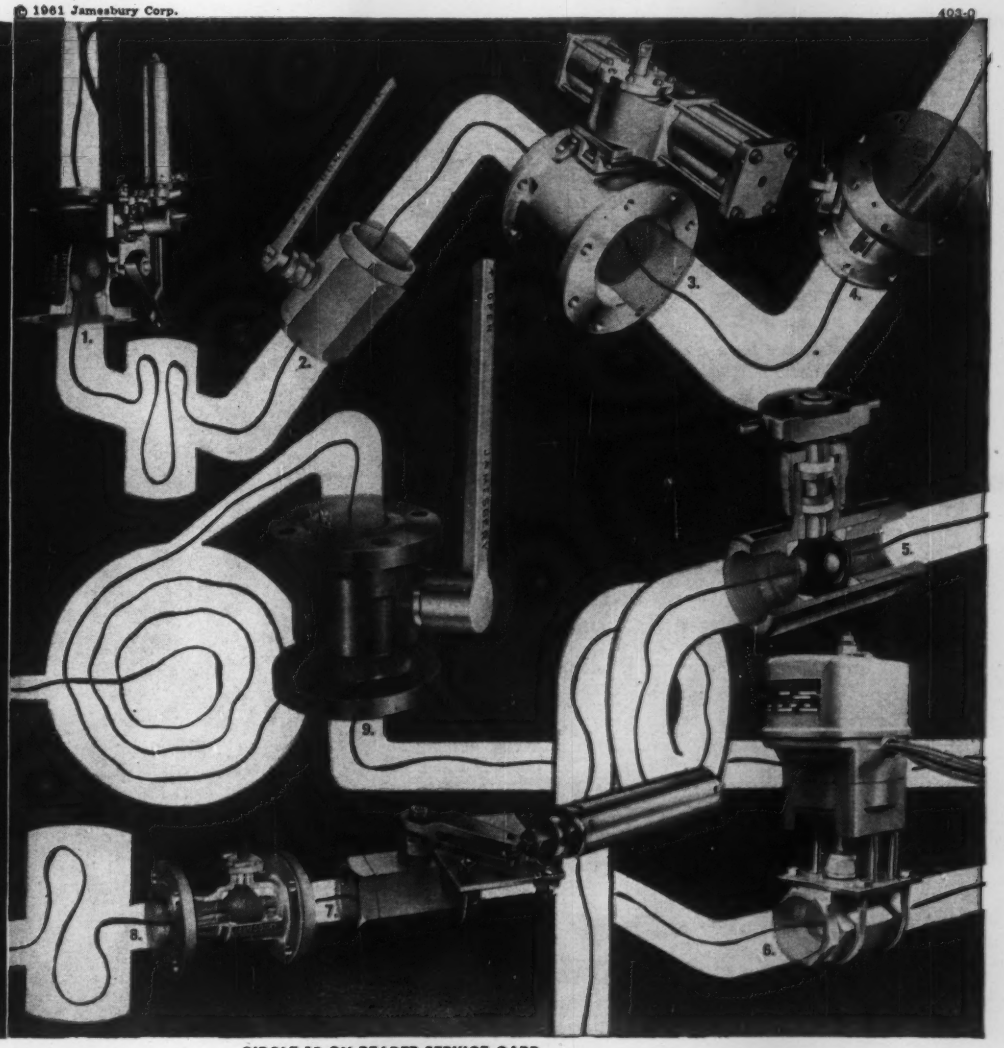
SIZES:

Screwed End: ¼" through 3".

Flanged: 150# series — ½" through 12", 300# series — ½" through 8"*.

*10" and 12" on application

*600# series on application.

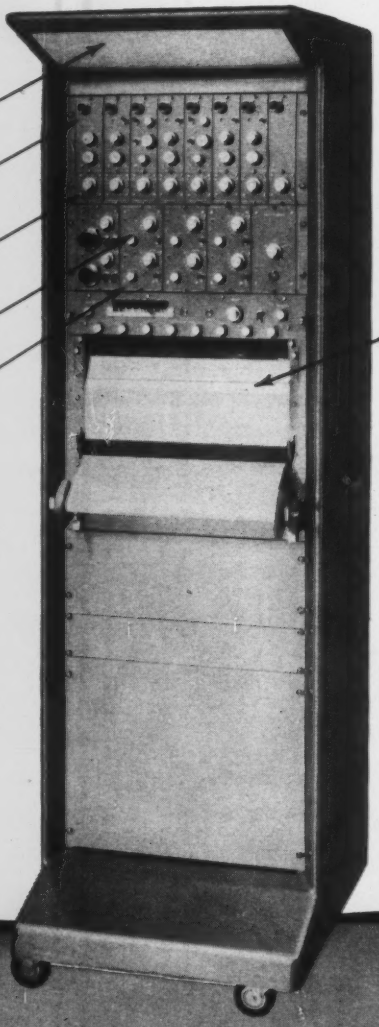


CIRCLE 15 ON READER-SERVICE CARD

OFFNER
ALL TRANSISTOR

TYPE R DYNOGRAPH

the most versatile . . . most sensitive direct writing unit available



Illuminated canopy

Type 9800 series input couplers provide all input, control and balance functions. Input available both front and rear.

Type 481 Preamplifier provides sensitivities from one microvolt to 5 volts per mm.

Type 482 power amplifiers—may be used without preamplifiers for up to 10 mv/cm sensitivity

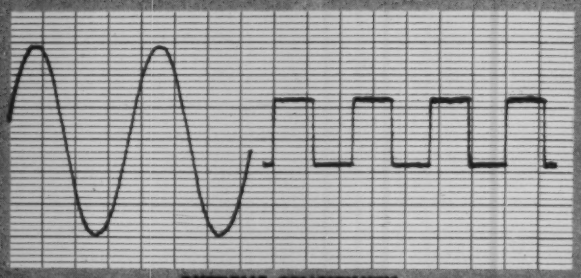
Zero suppression control

504-A paper drive—speeds from 1 to 250 mm/sec. Electrical speed shift 1 to 250 mm per minute available. Zero weave high precision drive, 850 ft. capacity (heat or electric) 1500 ft. (ink). Front loading, with full unobstructed record visible from front.

Combining all these features...

- *stable d-c sensitivity of one microvolt per mm*
- *true differential input*
- *high input impedance*
- *response to beyond 150 cps.*
- *reluctance, differential transformer, strain gage with a-c or d-c excitation, thermocouples, etc., used with all preamplifiers*
- *deflection time less than 1.5 milliseconds (2.5 ms with preamplifiers)*
- *fixed precision calibration*
- *instant warm-up*
- *precision source for d-c and 400 cycle excitation, self-contained*
- *zero suppression, twenty times full scale, both directions*

FULL SCALE, UNRETOUCHED CHARTS PRODUCED ON THE TYPE R DYNOGRAPH



EXTREME SENSITIVITY

10 Microvolt RMS Sine Wave — **Ten Microvolt D-C Square Wave**

Four recording media. Heat or electric rectilinear—ink or electric curvilinear. Readily convertible.

CIRCLE 16 ON READER-SERVICE CARD

All these features . . . plus 8 channels in only 35" of rack space. Whatever your application for direct writing records . . . you should investigate the ability of the Offner Type R Dynograph to do the job *better* and more *simply*. Using transistor circuits* developed and tested for over three years in thousands of channels of Offner equipment, the Type R Dynograph has already proved its superiority in practically every respect to *any other* direct writing oscillograph. Write on your company letterhead for literature giving details and specifications.

**Patents granted and pending*

OFFNER ELECTRONICS INC.

3910 River Road, Schiller Park, Ill.
(Suburb of Chicago)

Private industry spent $9.4 billion for research and development in 1959 says the National Science Foundation. This was 15% above 1958. Estimates for 1960 indicate a somewhat smaller annual increase (8%). The two industries that far exceeded all others in the amount of R&D expenditures in 1959 were aircraft and parts ($2,973 million) and electrical equipment and communication ($2,227 million). Next were chemicals and allied products ($928 million), machinery ($910 million), and motor vehicles and other transportation equipment ($863 million). These five industries accounted for more than four-fifths of all research and development expenditures by private industrial firms in 1959. More than half (57%) of the industrial R&D funds in 1959 came from the Federal Government, reflecting use of industrial facilities for the conduct of R&D on military and defense-related materials and equipment.

Computer census by John Diebold and Associates reports that number of large-scale computers delivered is now 541 (up 71% over 1 year ago), including 165 IBM 705 and 120 IBM 704; medium-scale computers delivered number 2417 (up 88% over 1 year ago)including 265 IBM 650 with tape or Ramac, and 119 Bendix G-15 with tape; small-scale computers number 2417 (up 76% over 1 year ago), including 1200 IBM 650 card-type, 575 IBM 305, 350 Royal-McBee LGP-30. Miscellaneous types delivered number 6296, including 4500 IBM 604.

Oil and natural gas study in period 1950-1975 by B. C. Netschert in Independent Petroleum Association Monthly reports: Total energy consumption will be 88% higher in 1975 than in 1955, gas 107% higher, coal will be up 70%; oil will be up 86%; electricity up 135%; natural gas liquids 183%. Natural gas will increase to 28.5% of total energy use. Oil production in 1975 will hit 4 billion bbl primary and 2 billion bbl secondary. Gas production will be 22.5 trillion cf in 1975 from estimated 1200 trillion cf supply.

Natural gas industry is sixth in size in USA, and construction scheduled for next 4 years is estimated at $3.5 billion, says Public Utilities Fortnightly.

Demand index for scientists and engineers (based on recruitment advertising volume) is July—100% (base month), August—97.6%; Sept.—107.7%, reports Deutsch & Shea, advertising firm.

Basic research funds totaled $344 million in 1959, which was 4% of total R&D funds, says NSF.

Canadian instrument market is 9 million pounds per year, of which about 2 million pounds is imported. USA supplies 90% of the imports; Britain 5%. Canada manufactured 8.5 million pounds of instruments in 1957, as shown in table. Of 18 largest Canadian instrument manufacturers, the US holds majority ownership of 15.

Value of Canadian Instrument Production in 1957

	£000	
Industrial thermometers	140	2.5%
Pyrometers and thermocouples	500	7.1%
Other temperature and hygrometric instruments	2,400	29.5%
Electrical measuring instruments	300	3.7%
Pressure instruments	600	7.6%
Flow and level gauges	600	7.6%
Control valves and regulators	1,100	14.0%
Combination instruments	2,200	28.0%

ICS NEWS

GE Expands Analog Computer Facilities

SYRACUSE, N. Y.—In a move to enlarge the services provided by the General Electric Electronic System Evaluator (GEESE) to military departments of the government and to industry, G-E's Defense Systems Department in Syracuse, N. Y. has named a team of 39 men, headed by Fletcher S. Crowe, to expand computer evaluation techniques and equipment for analog simulation.

Through the use of four analog computers and the facilities of GE's Defense System Department, GEESE will be able to analyze electronic sub-systems or systems on a company or customer-sponsored contract basis. Techniques have been developed for scaling radio frequencies down to audio frequencies so that complex communication and radar systems can be simulated operationally on analog computers.

Eleventh Iron & Steel Conference

PITTSBURGH, PA.—Two vice-presidents of leading steel companies will be on hand to speak to the attendees of the Eleventh Annual Conference on Instrumentation for the Iron and Steel Industry, March 8-9, 1961. The two-day conference will be held in the Pick-Roosevelt Hotel in Pittsburgh, Pa. Some 18 technical papers on steel instrumentation will be presented, to be capped by a banquet to be held Thursday night, March 9, at 6:30 P. M. An additional feature will be a field tour of the Jones and Laughlin Steel Corporation mill at Aliquippa, Pa.

UNIVERSITY OF ARIZONA's Applied Research Lab has built two new instruments, one electromechanical, the other electronic, to facilitate teaching of statistics.

UNIVERSITY OF ILLINOIS now has a program leading to PhD in nuclear engineering.

Pilot Plant And Process Automation Symposium

LOS ANGELES, CALIF.—The third annual Symposium on Pilot Plant and Process Automation will be held April 5th and 6th, 1961, at the Ambassador Hotel in Los Angeles. Attendance is limited to a small number (120) of invited, technical management personnel in the process industries. The symposium will again be sponsored by a group of instrument and automation equipment suppliers: (TRW Computers, Daystrom, Consolidated Systems, and Robertshaw Fulton Controls), but the program will be arranged and controlled by a users committee—Phillips Petroleum, the University of Arkansas, Celanese, Esso, and DuPont. Symposium Chairman is Frank Karasek of Phillips Petroleum. Coordinator is Mr. Jack Maguire, 202 N. Canon Drive Beverly Hills, Calif.

LIQUIDOMETER CORP. regrets to announce the death of *Herman Mueller*, manager, Special Products Dept., who died in the collision of two aircraft over Brooklyn on December 16, 1960.

VITRO CORP. of America has received an Air Force contract to evaluate reliability of TACAN (Tactical Air Navigation), a system which shows a military pilot continuously where he is with respect to an airfield or ground beacon.

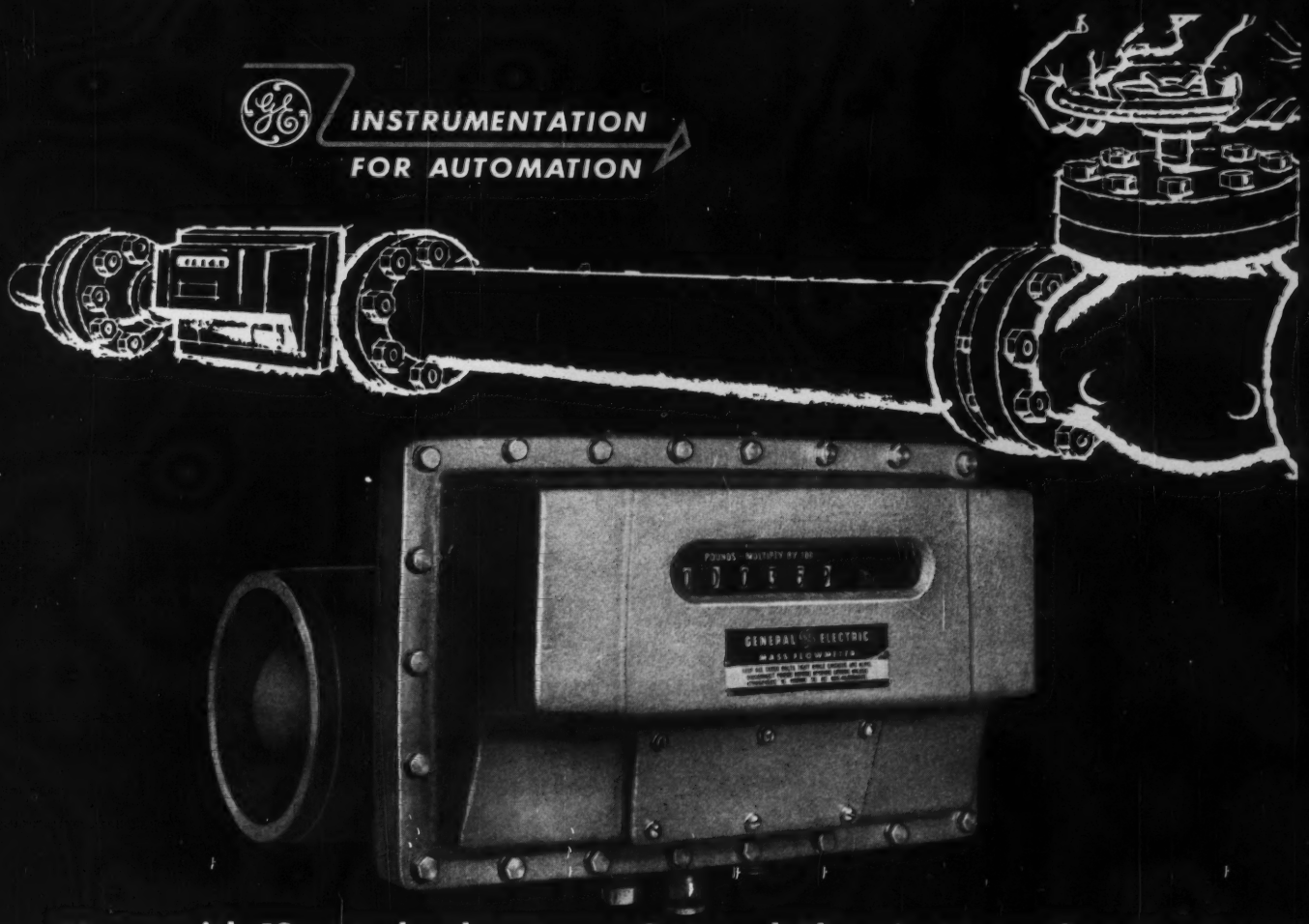
COMPUTERMAT INC., a service organization offering computer time on a self-service basis, has opened the first of several ComputerMats planned for the Los Angeles area. Heart of the center is an IBM 1620.

REPUBLIC AVIATION is using a new high-speed data system in its flight-test program of the F-105D supersonic fighter-bomber. Built by EPSCO, INC. to Republic's specifications, it centers around an airborne electronic converter which records performance data on magnetic tape in digital or numerical code. The tape is then evaluated by an IBM 704.

ESTERLINE-ANGUS recently gave its sales representatives a three-day intensive training course and previewed soon-to-be introduced new products.

FENSKE, FEDRICK & MILLER, INC., Los Angeles, has perfected a new Ground Approach Control System, known as FLEDCO, which is a combination of its own Incorama system with the Fledermaus Radar System which Contraves A. G. of Zurich, Switzerland, has produced with success. Fledco allows three-dimensional easy identification.

INSTRUMENTATION
FOR AUTOMATION



Now, with 12 standard ranges, General Electric Mass Flowmeter

PERFORMANCE-PROVED

. . . ON THE LINE! Today, many companies in the petroleum, chemical, petrochemical and natural gas industries are accurately measuring valuable process fluids directly in pounds with the General Electric True-Mass Flowmeter.

For example, these 12 applications have been performance-proved in actual service metering:

- **air • natural gas • alcohol • vinyl chloride**
- **freon • ammonia • liquid carbon dioxide**
- **ethylene • liquid petroleum gas • naphtha**
- **jet fuel • methane hydrogen mixtures**

(*Many more to come—let us know what your specific application is.*)

NEW ACCESSORIES FOR APPLICATION FLEXIBILITY:

Now, you can control batch blending accurately on a system basis with this flowmeter and new accessories which include:

counters—permit remote digital readout; **pre-set counters**—for automatic blending; **ticket and tape printers**—allow permanent and remote recording of flow.

AND *ALL* MODELS FEATURE:

- Accuracy independent of variations in density, pressure, viscosity and temperature
- Completely self-contained, self-integrating unit
- Low pressure drop
- Accuracy unaffected by fluctuation in power supply voltage and frequency
- Long-term stability for minimum maintenance and infrequent field calibration
- Quick response to rapid changes in flow without overshoot or lag
- Measurement in pounds—eliminates tedious conversions

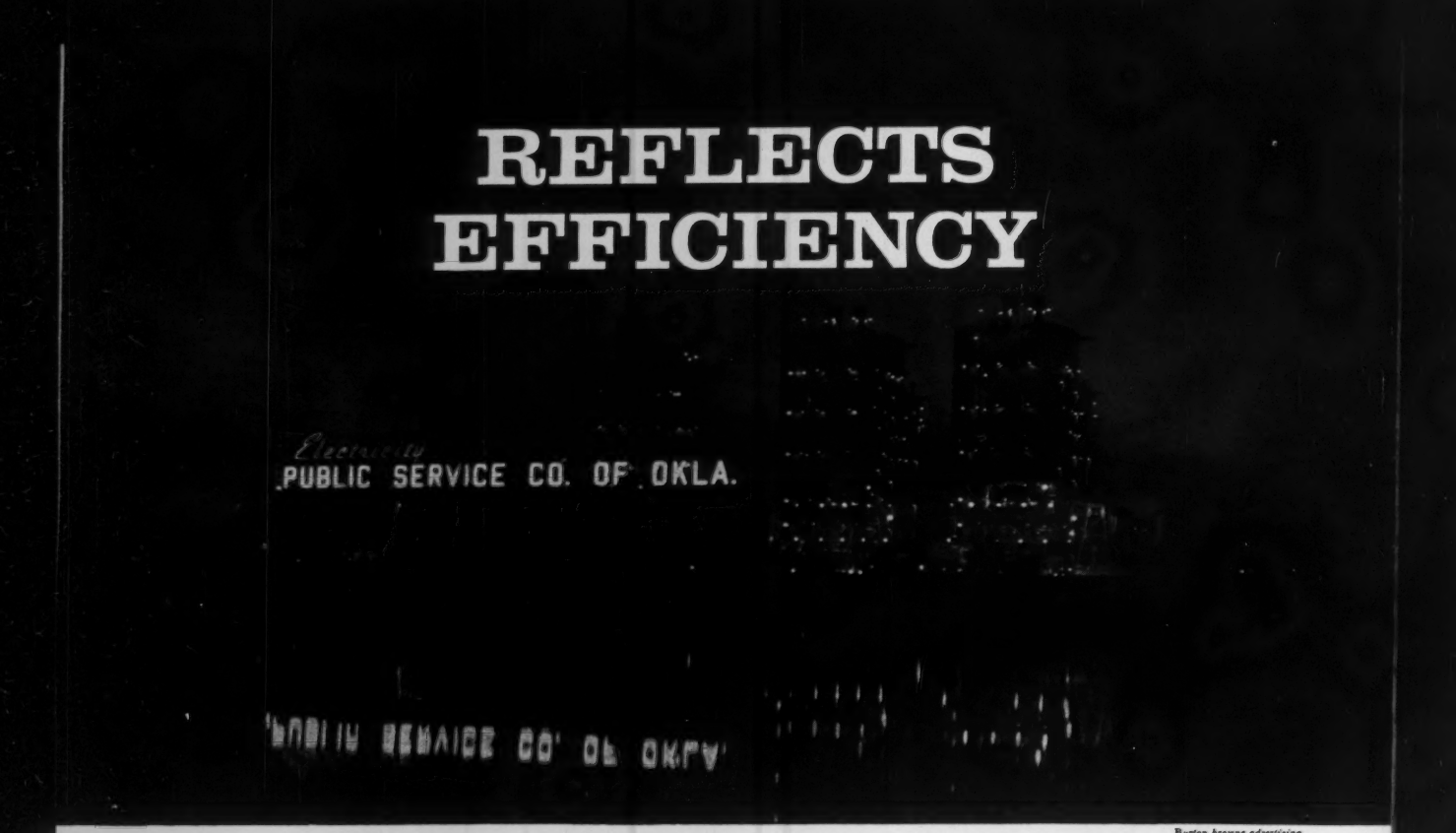
DO YOU HAVE AN APPLICATION for this revolutionary new instrument? Chances are you do, and we'd like to know about it. Contact your nearby G-E Sales Office, or write directly to General Electric Co., Section 599-03, Schenectady 5, N. Y. Be sure to ask for bulletin GEA-6925A. In Canada, contact Canadian General Electric Co., 940 Lansdowne Avenue, Toronto 4, Ontario. On applications in the natural gas industry, contact Black Sivalls and Bryson, Inc., P.O. Box 1714, Oklahoma City, Okla.

INSTRUMENT DEPARTMENT

GENERAL ELECTRIC

CIRCLE 17 ON READER-SERVICE CARD

REFLECTS EFFICIENCY



Burton browne advertising

because PANALARM REDUCES LOGGING TIME TO SECONDS...CURTAILS COSTLY OUTAGES

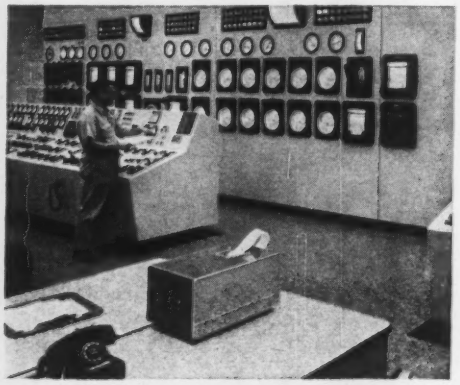
Public Service Co. of Oklahoma reports greater continuity of service and fewer costly outages from using PANALARM Annunciators in its new Tulsa station

PANALARM "flashing-ringback sequence" Recording Annunciator System converts raw data into usable information in seconds—a tremendous improvement over slow, old fashioned manual logging. Costly outages are fewer because of the speed and reliability with which off-normal conditions are registered.

The Recording Annunciator System sounds an alarm when trouble occurs. Simultaneously, it prints an accurate alpha-numeric digital record of the date and time of trouble and identifies the equipment that failed and/or returned to normal, eliminating possibility of operator error.

Another big advantage is that it continues receiving and recording information during emergencies, relieving the operator of this burden. The operator then concentrates his entire attention on ending the emergency. Later, a precise, sequential record is available for both operators and engineers to study as a basis for preventive maintenance and action.

For an optimum competitively priced Recording Annunciator System for your plant, talk to Panellit engineers.
Sales and engineering offices in all principal cities.



PANALARM ANNUNCIATORS record critical information on 7 turbine generators related to differential shutdown, overvoltage, ground detection, motor control, loss of field, pressures, temperatures, and shutdown or bus tie transfer operations.

For complete technical details on the Recording Annunciator, write for Bulletin 102A today.

PANALARM

PANELLIT *a division of ISI incorporated*

7401 north hamlin avenue, skokie, illinois–phone: orchard 5-2500

Annunciators • Control Panels • Data Systems • Contract Maintenance and Installation

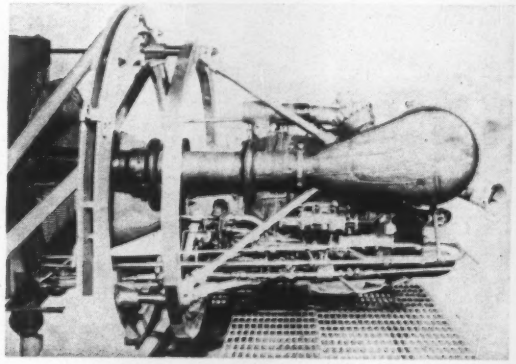
CIRCLE 18 ON READER-SERVICE CARD

HUGHES AIRCRAFT has built a satellite which will enable the United States to place a stationary communi-

cations relay station in space in 1961. With its aid, hundreds of telephone circuits and direct television across the ocean will be made possible. Weighing only 32 lb, it contains 2,700 solar cells.

GENERAL ELECTRIC has announced GECOM (General Compiler), a new programming technique whereby English language is automatically translated into computer code. GECOM is compatible with COBOL, the universal business language, ALGOL, the new algorithmic language, and the new TABSOL system, a method for describing the decision-making processes in table, or tabular, form.

HYDROMATICS, INC. has designed and manufactured the Flo-Ball valves for the Air Force's X-15 air-space vehicle, expected to go to 100 miles altitude with 4000-



mph speed. Fuel, consisting of liquid oxygen at —297°F and liquid ammonia must flow separately and reach the combustion chamber in precise proportions, controlled by the valves.

NEW APPLICATIONS

PERFORMANCE MEASUREMENTS CO. in cooperation with Ford's quality control engineers has built EAGER (Electronic Audit Gager), a system which in 15 minutes checks out all electric components in Lincoln Continental automobiles before they leave the factory. Signals are projected by film onto a screen which the inspector observes and evaluates.

COMPUTER CONTROL COMPANY has built a digital language translator for the U. S. Army's White Sands Missile Range. UTTC (Universal Tape-to-Tape

Converter), accepts as input digital magnetic tapes from radar, telemetering, etc. and converts the data into magnetic-tape output suitable for analysis by high-speed computers. It has passed all acceptance tests.

CONTROL DATA CORP. and its 1604 computer customers recently held the sixth conference of CO-OP, their cooperative project, in Princeton.

Instrument Short Course

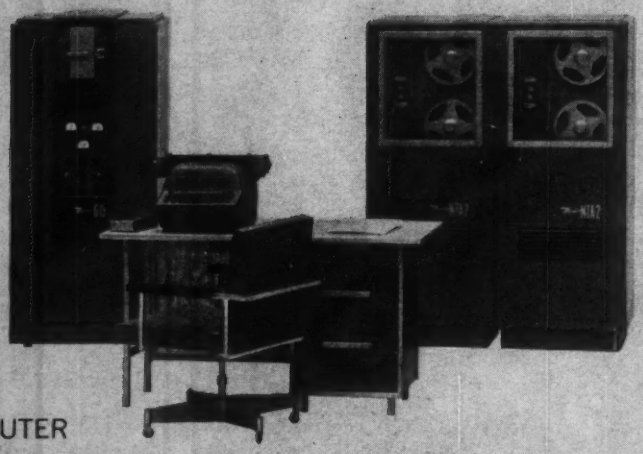
The tenth annual instrument short course, March 28-29, 1961, is co-sponsored by the Southern California Meter Association and Los Angeles Harbor Junior College (1111 Figueroa St., Wilmington, Calif., where it will be held). Registration begins 1:00 p.m. March 28 in the foyer of the main building. Registration fee is $2.50.

Mr. C. B. Moore, President, Moore Products Co., will present the keynote address on Tuesday March 28 at 2 p.m.

The *General Sessions Division* will offer lectures on: (1) Gas Laws, (2) Fundamentals of Measurement and Control, (3) Basic Electronics, (4) Basic Electricity, (5) Fundamentals of Force Balance Instruments, (6) Basic Control Modes, (7) Orifice Meter Coefficients, (8) Basic Semi-Conductors, (9) Unusual Measuring Devices, (10) Process Principles, (11) Boiler Combustion Controls, (12) Nuclear Applications, (13) Steam Plant Instrumentations, (14) Computer Control, (15) Beginnings in Automation, (16) Standard Cubic Feet Automatically, (17) Smog and the A.P.C.D., (18) New Methods in Oil Field Instrumentation, (19) Telemetering, (20) Modern Technology, (21) Water Injection, (22) Application of Analog Devices, (23) Control Valves.

The *Maintenance Methods Division* will offer classes in the repair, operation, and maintenance of Level Controllers, Valve Positioners, Recorders, Pneumatic Transmitters, Transmitters, Electric Potentiometers, Ranarex Gravitometer.

Exhibits will be open from 3:15 p.m. to 9:00 p.m. Tuesdays and 9:00 a.m. to 6:00 p.m. Wednesday.



ALGO*

FOR THE BENDIX G-15 COMPUTER

Speeds and Simplifies Problem Solving

ALGO extends the problem-solving horizon of every engineer, focusing the speed and precision of the Bendix G-15 computer on any algebraically stated problem. ● A true mathematical equation solver, ALGO permits any engineer or scientist to program the computer in universal mathematical language. No previous knowledge of computers or programming is needed. Input/output, computation and data handling are all automatically controlled by the G-15 computer. ● Compare the number of steps in the ALGO program illustrated below with the number required to solve the same problem on a slide rule, desk calculator or any other computing system. You will see the time and cost-saving significance of this new Bendix G-15 automatic programming aid. ● Specifically designed to take advantage of the computing power and flexibility of the proven G-15, ALGO is the newest addition to an extensive library of Bendix automatic programming systems. See how the low-cost Bendix G-15 and ALGO combine to broaden application boundaries. Learn how this powerful team can save you valuable time . . . and greatly simplify problem solving.

* AN ALGEBRAIC COMPILER BASED ON INTERNATIONAL ALGOL.

PROBLEM: $$I = \frac{E}{\sqrt{R^2 + (6.2832\,FL - 1/6.2832\,FC)^2}}$$

(For values of R F & L as specified. For values of E ranging from 100 to 300 in increments of 50. For values of C ranging from .00002 to .000021 in increments of .0000001)

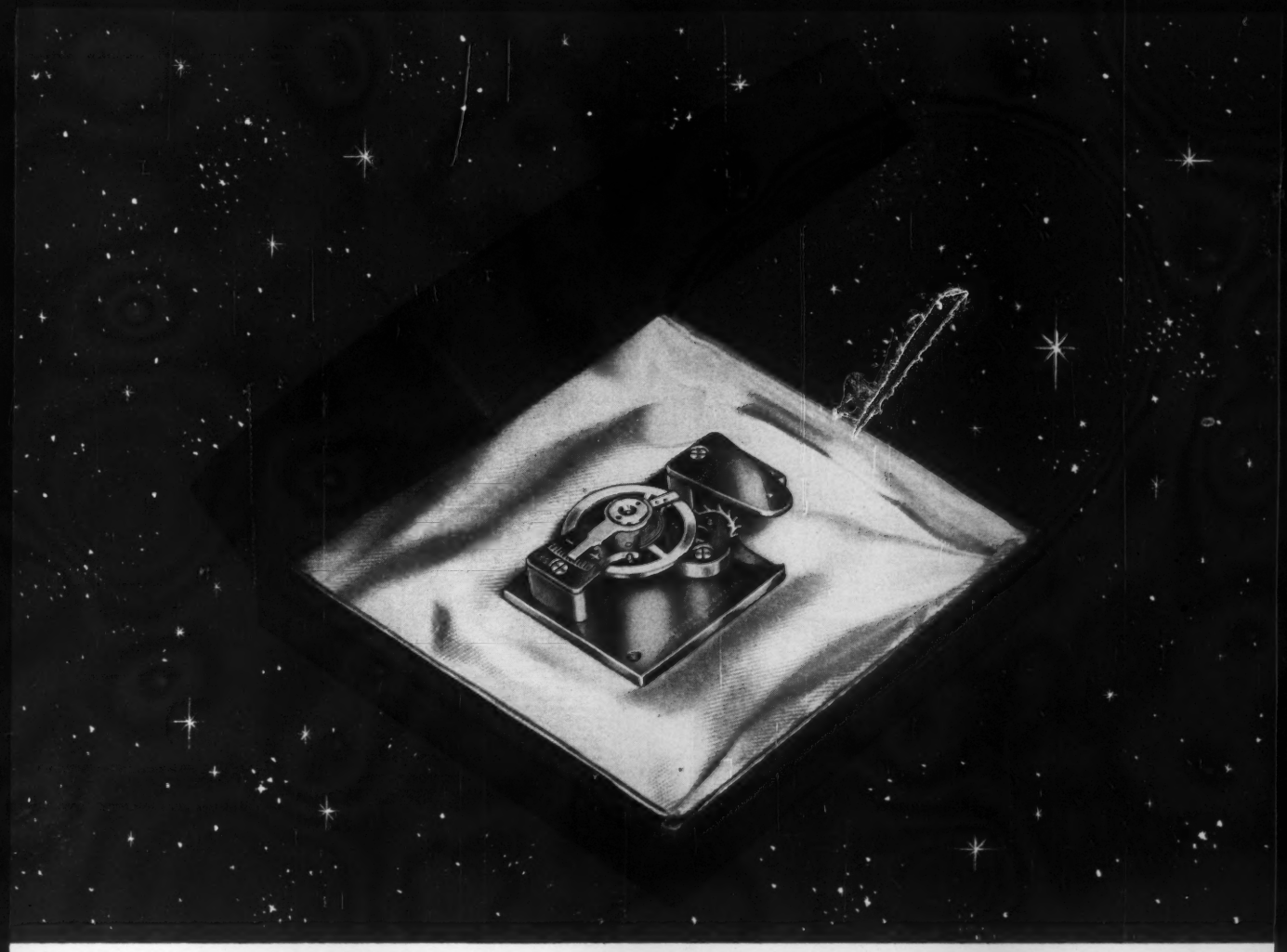
COMPLETE ALGO PROGRAM:

```
BEGIN ⑤
R = 10 ⑤
F = 60 ⑤
L = ₀2 ⑤
FOR E = 100(50)300 BEGIN ⑤
FOR C = ₀00002(₀0000001)₀000021 BEGIN ⑤
I = E/SQRT(R ↑ 2 + (6₀2832 * F * L — (1/(6₀2832 * F * C))) ↑ 2) ⑤
PRINT (FL) = E ⑤
PRINT (FL) = C ⑤
PRINT (FL) = I ⑤
```

Write on your letterhead for the self-teaching ALGO manual.

Bendix Computer Division
DEPT. J-23 LOS ANGELES 45, CALIF.

THE Bendix CORPORATION



This "jeweled" escapement brings you fine watch quality in chart drives

See how easy it is to convert to seven different rotation rates

The main arbor on the basic chart drive has a rotation rate of seven days. Economical snap on turrets convert this rate to 8 day, 15 day, 16 day, 24 day, 30 day, 31 day and 24 hour rotation. No tools are required and you can even change chart rotation without removing the drive from the instrument.

Now, for the first time you get the extra value of a jeweled movement. This superior construction makes Rockwell chart drives more accurate and sensitive than ordinary chart drives. It requires less power to drive and is extremely durable since there are seven hard jeweled surfaces to overcome friction and wear.

You can use these jeweled movement chart drives *with profit* to power all your recording instruments. They will adapt into practically any instrument case. Speed changing turrets (see left) permit varying rotation rates at will. Write for bulletin. Rockwell Manufacturing Company, Dept. 58-M, Pittsburgh 8, Pa. In Canada, Rockwell Manufacturing Company of Canada, Ltd., P.O. Box 420, Guelph, Ontario.

JEWELED CHART DRIVES

another fine product by

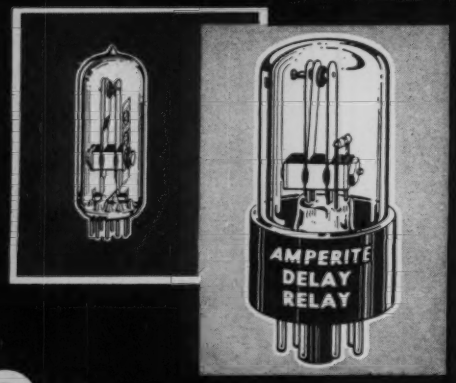
ROCKWELL

← CIRCLE 19 ON READER-SERVICE CARD

CIRCLE 20 ON READER-SERVICE CARD

AMPERITE

Thermostatic DELAY RELAYS



Only a glass seal offers true hermetic sealing . . assuring maximum stability and life!

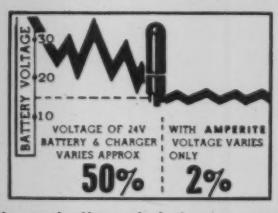
Delays: 2 to 180 seconds . . . Actuated by a heater, they operate on A.C., D.C., or Pulsating Current . . . Being **hermetically sealed,** they are not affected by altitude, moisture, or climate changes . . . **SPST only**—normally open or normally closed . . . Compensated for ambient temperature changes from —55° to +80° C. . . . Heaters consume approximately 2 W. and may be operated continuously . . . The units are **rugged, explosion-proof, long-lived,** and—**inexpensive!**

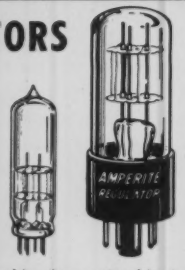
TYPES: Standard Radio Octal, and 9-Pin Miniature . . . **List Price, $4.00.** Also — **Amperite Differential Relays:** Used for automatic overload, under-voltage or under-current protection.

PROBLEM? Send for Bulletin No. TR-81

AMPERITE

BALLAST REGULATORS





Hermetically sealed, they are not affected by changes in altitude, ambient temperature (—50° to +70° C.), or humidity . . . Rugged, light, compact, most inexpensive . . . . . **List Price, $3.00.**

Write for 4-page Technical Bulletin No. AB-51

AMPERITE

561 Broadway, New York 12, N. Y. . . . . CAnal 6-1446

In Canada: Atlas Radio Corp., Ltd. 50 Wingold Ave., Toronto 10

CIRCLE 21 ON READER-SERVICE CARD

IGS STOCK REPORT

Further information may be obtained from the Research Department, Bache & Co., 36 Wall Street, New York 5, N. Y.

NEW YORK STOCK EXCHANGE

PRICE RANGE FOR 1961 THRU JANUARY 16, 1961

	High	Low	Price As Of 1/16/61
ACF Industries	52	35 1/8	47
Aeroquip Corp.	40 5/8	22	25
Allis Chalmers	40	22	26 7/8
American Chain & Cable	51 3/4	40 1/4	46 1/2
Amer. Mach. & Foundry	91 7/8	49 1/2	87 3/4
Amer. Mach. & Metals	58 1/4	31 3/4	38
American Optical	67	43 1/4	56
American Tel. & Tel.	108 1/2	79 7/8	106 7/8
Ampex Corp.	42 1/4	19 1/2	22 1/8
Arc Equipment	25 7/8	19	21 1/8
Bauch & Lomb Optical	58 7/8	34 1/2	43 1/8
Beckman Instruments	103 3/4	62 1/2	90 3/4
Bell & Howell	57 1/2	37 5/8	50 3/4
Bendix Aviation	74 1/2	56 1/4	69 1/8
Boeing Airplane	40 1/4	23	39
Bullard	17 7/8	10 3/8	13 7/8
Bulova Watch	23 3/4	14 1/8	16 3/4
Burroughs	40 3/8	26 1/4	29
Carborundum	49 7/8	39 1/4	46 1/4
Cinn. Milling Machine	39 5/8	26 1/2	39
Clevite	72 1/2	42	55 1/4
Columbia Broadcasting Sys.	45 1/4	34	36 1/2
Consol. Electronics	80 3/4	42 1/4	41 1/2
Corning Glass	186	124	177
Curtiss Wright	31 1/8	14 5/8	17 1/4
Cutler-Hammer	96	67 1/4	72 1/2
Daystrom	49 3/8	27 1/2	31 1/2
Douglas Aircraft	42 3/8	27	30 1/2
Eastman Kodak	136 1/4	94	110 3/8
Eaton Mfg.	46 7/8	28 1/2	34
Electric Auto-Lite	54 1/2	44 1/2	45 1/4
Elgin Watch	19 1/8	10 1/2	12 3/8
Emerson Electric	58 1/4	33	57 3/8
Engelhard Industries	23	16 3/4	20 5/8
Food Mach. & Chem.	63	44 1/2	63 1/4
Garrett	59	42 1/8	52 1/2
General Controls	29 5/8	15 3/4	18 1/2
General Dynamics	53 3/8	33 1/2	43 3/8
General Electric	99 7/8	66 7/8	70
General Instruments	50 3/8	22 1/2	41
General Mills	33 1/2	23 7/8	33 3/8
Gen. Precision Equip.	66 5/8	43 1/2	56 1/2
Gen. Railway Signal	36 7/8	23 1/4	30
Gen. Tel. & Elect.	34 1/8	23 3/4	27 1/4
General Time	33 1/8	12 1/2	14 3/8
General Tire & Rubber	81 3/8	41 5/8	60
International Bus. Mach.	622 1/2	407 1/4	613
International Resistance	41 5/8	18 1/4	28 1/4
Internat'l. Tel. & Tel.	48 7/8	32	47 1/8
I-T-E Circuit Breaker	44 1/4	18 1/8	21 1/2
Lear Inc.	23 1/2	13 5/8	17 3/8
Litton Industries	96 5/8	57 5/8	89 1/8
Lockheed Aircraft	32 7/8	18 5/8	28 5/8
Magnevox	55	31 3/4	47 3/4
Mallory	50 1/4	33	38
Manning, Maxwell & Moore	27 1/2	19 5/8	24
Minneapolis-Honeywell	178 3/4	123 5/8	146
Minnesota Mining & Mfg.	88	60	71 1/2
Motorola	98	60 1/2	77 1/2
National Acme	54 3/4	40	53 7/8
National Cash Register	70 7/8	49 7/8	67 1/4
Neptune Meter	34 3/8	24	28 3/4
North American Aviation	50 1/4	29 5/8	48 3/4
Northrop Aircraft	47	24 3/4	44
Otis Elevator	64 1/2	36 3/4	61 1/2
Philco Corp.	38 1/4	15 7/8	19
Radio Corp. of Amer.	78 3/8	46 1/2	50 5/8
Raytheon Mfg.	53 3/8	30 1/4	38 1/2
Reliance Electric	68 5/8	43 1/8	51
Rheem Mfg.	28 7/8	12	15 1/4
Robertshaw Fulton	55	33 1/4	37
Royal N Mc Bee	21 3/8	11 7/8	14
Sangamo Electric	21 1/2	13 1/8	15
Siegler Corp.	43	23 5/8	29
Sperry Rand	26 1/4	18 3/8	23 7/8
Square D	37 7/8	25 1/2	30 1/8
Standard Kollsman	30 1/2	12 5/8	25 5/8
Starrett (L.S.)	20	16	18
Stewart-Warner	33 1/2	23	25 3/8
Telautograph	24 1/2	6 7/8	14 3/8
Texas Instruments	256 1/4	148 1/4	168 1/2
Thompson-Ramo-Wooldridge	70 1/2	46 7/8	69 3/8
Tung-Sol Electric	40 1/2	24 3/4	29 1/2
Underwood Corp.	57	23 3/4	45 1/2
Union Carbide Corp.	148 1/2	106 1/2	123
United Shoe Machinery	64 3/8	50	55 3/8
Varian Associates	67 1/2	38 1/8	50 3/4
Wallace & Tiernan (new) (a)	30	26 3/4	27 3/8
Western Union	57	38 1/4	44 5/8
Westinghouse Air Brake	32 5/8	21 1/8	23 3/4
Westinghouse Electric	65	45	46 5/8
Worthington Corp.	66	41 1/2	51 1/4

These prices and price ranges are given as printed in the Wall Street Journal.

(a) Stock Split 2-for-1.

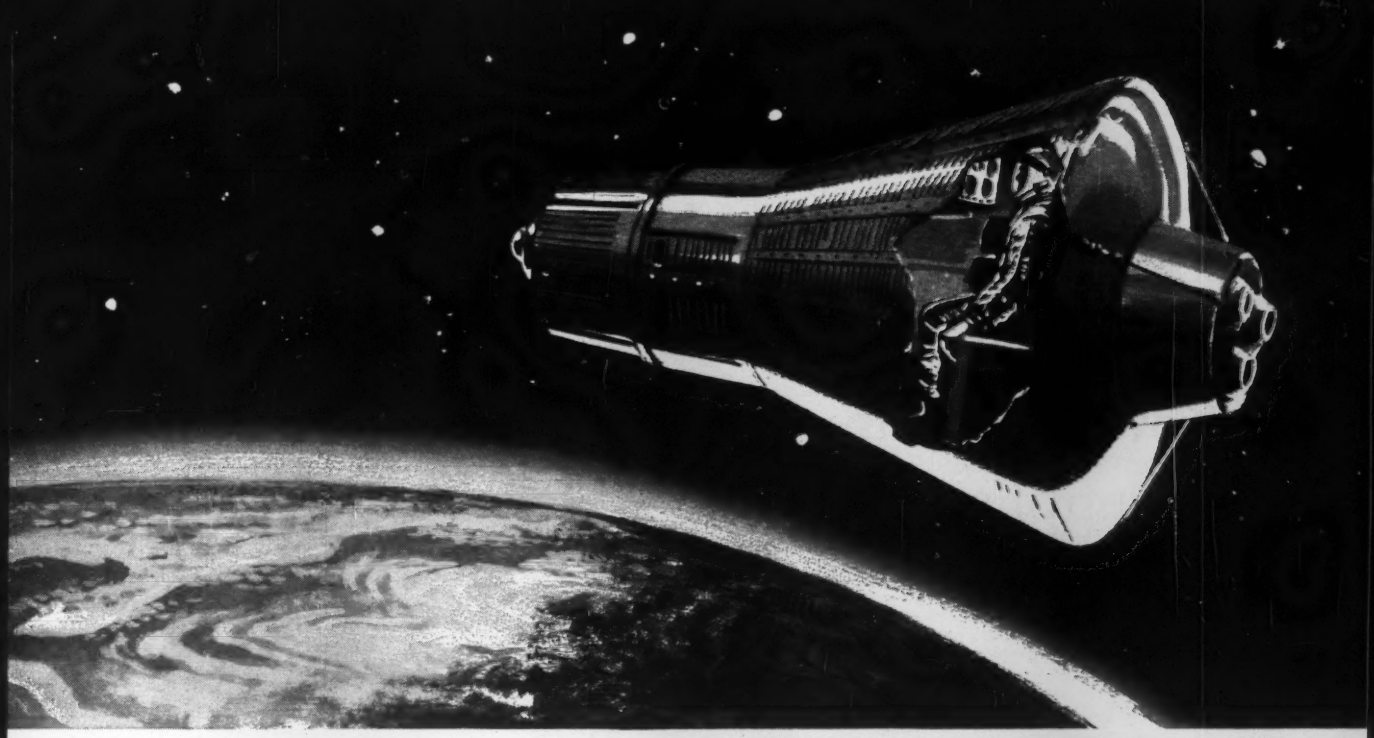
AMERICAN STOCK EXCHANGE

PRICE RANGE 1961 THRU JANUARY 16, 1961

	High	Low	Price As Of 1/16/61
American Meter	52	39	45 3/4
Barry Wright Corp.	25 1/2	13 5/8	15 1/2
Belock Instruments	25 3/8	13 1/8	15 1/4
Benrus Watch	8 7/8	5 3/8	6 1/4
Breeze Corp.	8 5/8	4	5 5/8
Bunnell & Co.	9	6	7 7/8
Clark Controller	23 5/8	15 1/2	18 5/8
Clarostat Mfg.	16 3/8	9 7/8	13
Clary Corp.	11 1/2	6 3/4	9 1/2
Cubic Corp.	69	39 5/8	54 1/2

Continued on page 197

CIRCLE 22 ON READER-SERVICE CARD ⟶



Orbiting spacecraft of NASA's Project Mercury will be tracked by a global arrangement of 18 communications stations.

Keeping track of a man in orbit

One day this year, the first U.S. astronaut may be rocketed into a globe-circling orbit, some 120 miles in space. Although he will be a mere dot in the heavens, a vast world-wide network of eighteen tracking stations—including two operating from ships at sea—will provide monitoring of every phase of the high-flying astronaut's journey in his orbiting spacecraft.

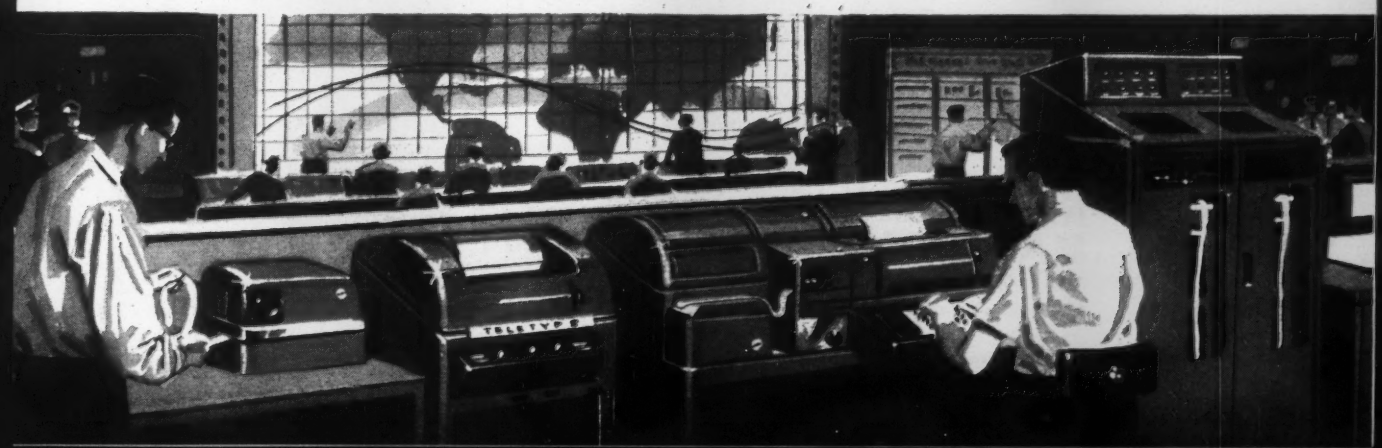
Linking each of the tracking stations with the project's Space Flight Center at Greenbelt, Maryland, and Mercury Control Center at Cape Canaveral, Florida, will be an array of Teletype equipment —Model 28 page printers, automatic send-receive sets and punched tape units. These Teletype communications devices will record and relay flight data collected by tracking and telemetering equipment from the spacecraft's instruments to the Flight Center, where an elaborate complex of data processing machines will coordinate and interpret flight data and provide directive information for the world-wide network of tracking stations.

Teletype Corporation is indeed proud to be a part of the Western Electric industrial team selected by the National Aeronautics and Space Administration (NASA) to build the vast communications network so vital to Project Mercury.

TELETYPE®
CORPORATION
SUBSIDIARY OF *Western Electric Company* INC.

Dept. 22-B, 5555 Touhy Ave., Skokie, Ill.

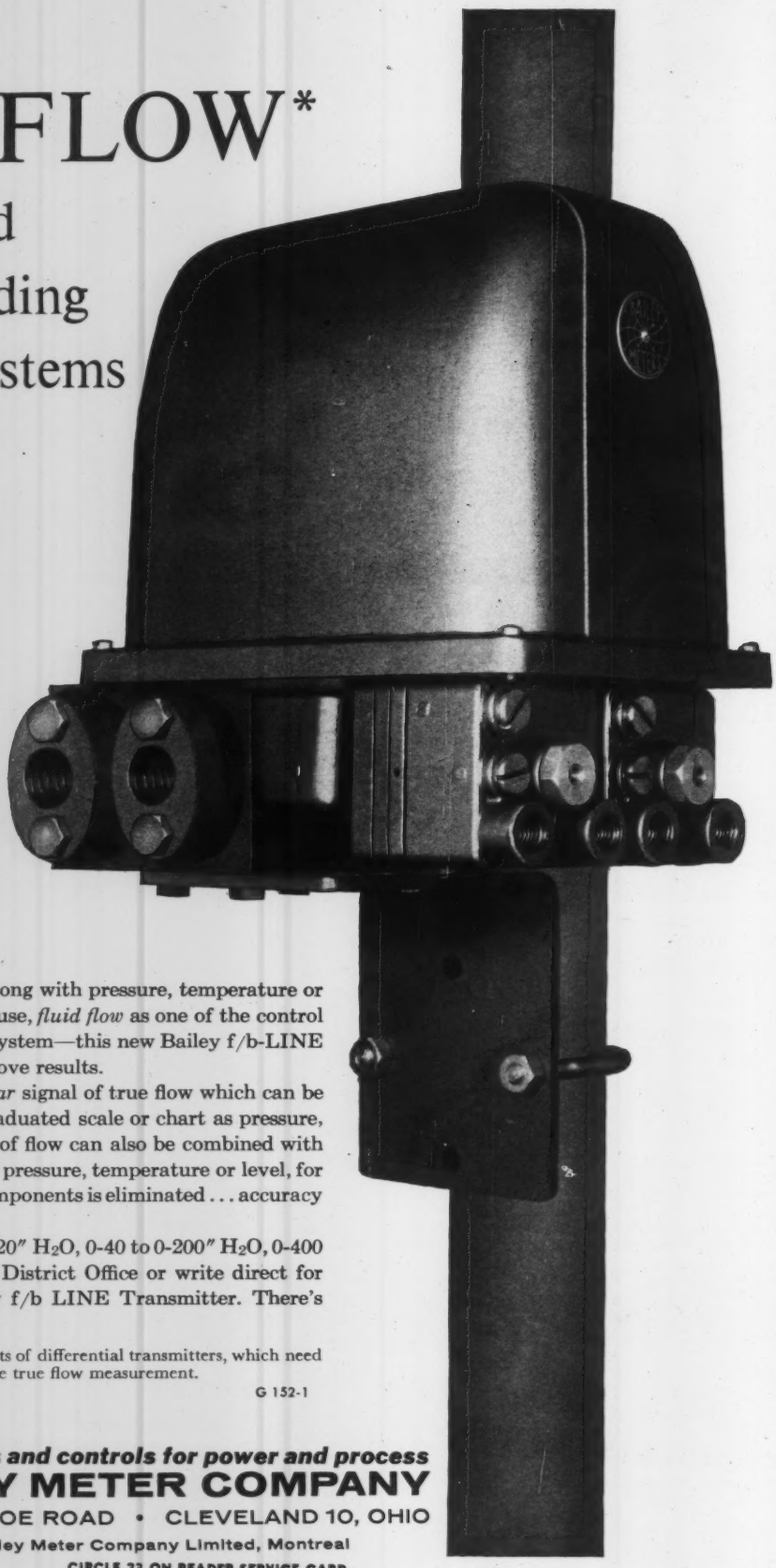
Teletype page printer, tape punch and reader units will be used throughout Project Mercury's global communications network to gather and relay flight data.



Measures

TRUE FLOW*

to simplify and improve recording and control systems



If you intend to record *fluid flow* along with pressure, temperature or level—or if you now use, or plan to use, *fluid flow* as one of the control factors in a multi-element control system—this new Bailey f/b-LINE Transmitter can simplify and improve results.

It measures and transmits a *linear* signal of true flow which can be recorded on the same uniformly graduated scale or chart as pressure, temperature and level. This signal of flow can also be combined with other linear signals such as those of pressure, temperature or level, for improved control. Need for extra components is eliminated . . . accuracy of flow reading is increased.

Wide selection of ranges: 0-4 to 0-20″ H_2O, 0-40 to 0-200″ H_2O, 0-400 to 0-2000″ H_2O. Call your Bailey District Office or write direct for complete data on the new Bailey f/b LINE Transmitter. There's nothing like it.

*As opposed to pressure-drop measurements of differential transmitters, which need external square root extractors to produce true flow measurement.

G 152-1

BAILEY METERS

Instruments and controls for power and process

BAILEY METER COMPANY

1041 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

CIRCLE 23 ON READER-SERVICE CARD

AMERICAN STOCK EXCHANGE

Continued from page 194

Dynamics Corp. of Amer.	13 3/4	6 5/8	8 3/8
El-Tronics	8 1/8	4	5 3/4
Electronics Corp. of Amer.	19 1/2	8 1/8	12
Fairchild Camera & Instrument	201 3/4	110 1/4	145 1/4
Fischer & Porter Co.	21 3/8	16	20 1/8
Giannini Controls	68 3/8	39	55 1/4
Globe Union	34 3/4	20 5/8	28 3/4
Hazeltine Corp.	31 1/2	20	27 3/8
Loral-Electronics (new) (a)	36 1/2	23 1/8	32 1/2
National Research	23 1/8	13 1/8	18
New Haven Clock	2 7/8	1	1 1/4
Nuclear Corp. of Amer.	5 1/8	2 1/8	4 5/8
Philips Electronics, Inc.	47 3/8	31 1/2	33 1/2
Pneumatic Scale	59 3/4	35	41
Polarad Electronics	36 5/8	17	19 1/2
Servo Corp. of Amer.	24 1/2	9 1/4	11 5/8
Servomechanisms	16	7 1/2	8 1/4
Statham Instruments Inc.	40 1/4	25 3/4	27 1/4
Textron Electronics	18 3/4	8 5/8	11 1/4
Victoreen Instrument Co.	17 1/2	9 3/4	15 1/4
Waltham Prec. Instr. Co.	3 1/2	1 1/2	1 7/8

These prices and price ranges are given as printed in the Wall Street Journal.

Barry Controls merged with Wright Line, Inc., new name is Barry Wright Corp.

(a) Stock split 3-for-1.

OVER THE COUNTER

	Quotation As of January 16, 1961	
	Bid	Asked
Aerovox Corp.	8 1/2	9
Argus Corp.	35 1/8	36
Black Sivalls & Bryson Inc.	13	13 1/2
Computer Systems	8	9
Eitel Mc Cullough	17 1/4	17 7/8
Electro Instruments	25 1/2	27
Electronics Associates	28	29
Erie Resistor Corporation	10 3/4	11 3/4
Fisher Governor Co.	20 1/2	21
Foxboro Company (new)	47	48 1/2
Nagan Chemicals & Controls	45 1/2	47
Industro Transitor	4 5/8	5 1/8
Liquidometer Corp.	13 1/2	14 1/2
W.L. Maxson	10 1/2	11
Penn Controls	21	22
Speer Carbon, Inc.	19	19 1/4
Sprague Electric	54 1/2	56 1/2
Taylor Instruments (new)	38	39 1/2
Telechrome Mfg. Corp.	12 1/2	13
Telecomputing Corp.	7 1/4	7 3/4
Vitro Corp. of Amer.	11 3/4	13 1/8

CHARTS
for Recording Instruments
We offer to the Instrument Maker Charts for all methods of Recording: Pen, Ball Point, Electrical, Thermal, Pressure and Metallic Stylus.
Uniform accuracy is assured through the use of specialized equipment operated under controlled atmospheric humidity conditions.
GUBELMAN
CHARTS INCORPORATED
100-6 E. KINNEY ST., NEWARK 5, N. J.

solve the

BIG

problem in

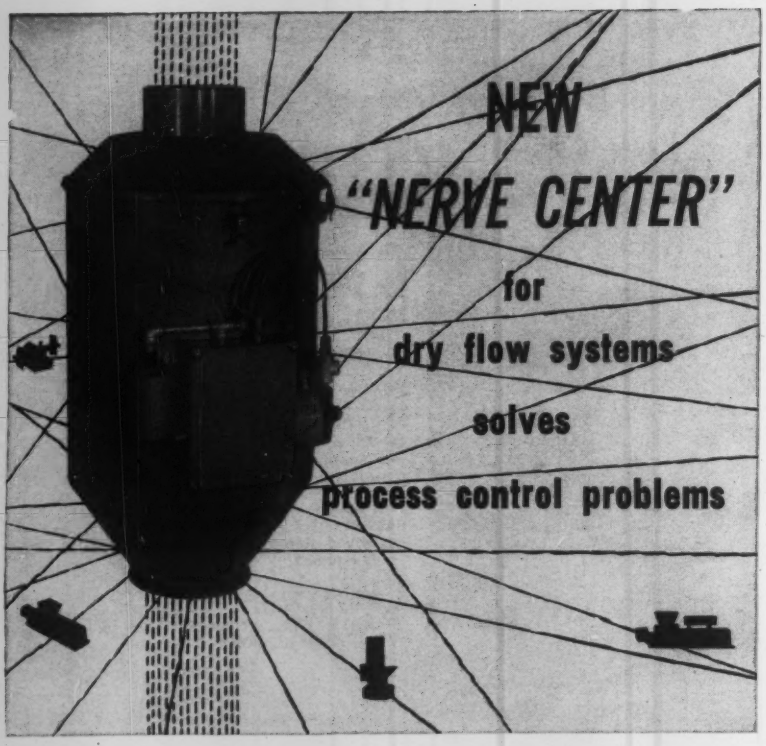
small

flow measurement

Metering small flows in test labs, pilot plants and research centers with Daniel honed flow sections gives you the edge in accuracy. How? Because Daniel flow sections *give reliable duplication of performance* to overcome a big problem in small flow measurement. Each unit is manufactured just like the previous one to report the most accurate signal on any make differential recorder or indicator.

Inside diameters of each unit are honed to plus or minus .001" tolerances. Materials available . . . carbon and 316 stainless steel, others on request. Operating pressures from 0 to 1440 P.S.I. (Gage) C.W.P., 600 lbs. A.S.A. or higher. Sizes . . . ¼", ½", ¾" and 1-inch. Send for your copy of Daniel catalog section "O".

CIRCLE 24 ON READER-SERVICE CARD



The new W&T Massometer® senses flow in closed systems. It measures dry, free-flowing materials and translates the results into a 3-15 psi signal. The unit can be used to indicate or record. It also controls proportional blending . . . helps solve problems in all kinds of control situations.

And the Massometer does all this without breaks in your closed system. Air-tight construction means a flow-sensing unit that seals dust in . . . seals contamination out. It is compact and easily installed, fits neatly into the line. Stainless steel for parts exposed to the flow stream and dust-tight motor casing assure years of maintenance-free service.

The Massometer is calibrated with any maximum output between 40 and 200 lbs. per minute. Maximum volumetric capacity is 6 cubic feet per minute. Repeatability within ±0.2% of full scale assures stable performance.

By generating a signal proportional to flow, the W&T Massometer brings a new look to ratio control. Its versatility means more accurate batch processing, or helps create continuous processing in new or existing systems.

For information, write Dept. M-50.48

WALLACE & TIERNAN INCORPORATED
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CIRCLE 25 ON READER-SERVICE CARD

I&CS READER INQUIRIES

Continued from p. 175

Liquid Level Control

President of machine company is interested in liquid-level sensor and control of probe or float type for use with non-conductive liquid consisting of trichlorethylene at 190°F, contaminated with mineral oils, machine chips, lint, and fine abrasives. If float type, 1" differential is desired. 110-v signal for low-level cut off, high-level warning, and automatic feed control—constant level make is required. A-6101

Fluid Dynamics

Design engineer with missile company would like to find a way of "calculating velocity of liquid due to an immersed heat source and subsequent prediction of how to deflect vertical stream by introduction of cool stream." A-6102

Electronic Timing System

Assistant to president of wholesale merchandizer seeks assistance from digital-clock manufacturer for perfecting timing system to be used on qualification runs in auto races. Specifications include: Actuation by electric eye light beam; total count—0 to 99.999 sec; permissible error—±0.001 sec/min; digital readout; portable, with 6- or 12-v battery, or reliable operation from 60-cycle line; with reset and hold mechanism. A-6103

Printing Integrator and Timer

Chemical engineer of electric utility company seeks a combination printing integrator and timer with five digits and capable of totalizing electrical impulses at a maximum rate of two impulses per minute. Electrical printout on cash-register tape is required with day of week and time of day. Data-processing or computer-type devices are not sought. A-6104

Absolute Pressure Gages

Design engineer with missile manufacturer seeks 6" or 8" absolute-pressure gages (bellows type) with 0-to-80 psia range. A-6105

Precision Resistance Thermometer

Australian instrumentation firm seeks resistance thermometer with platinum element and mean temperature coefficient of 0.00392 or greater between 0 and 100°C. Resistance at 0°C should not be greater than 25.5 ohms, or less than 0.25 ohms and should not drift more than the equivalent of 0.02°C after 10 hrs at 1000°C. Range 0-1000°C (or 0-1100°C). Element to be in ceramic sheath one cm in dia or less, and 50 cm long. A-6106

I&CS EVENTS

Meeting & Sponsor	Date and Place
Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy —ACS, SSP	Feb. 27-Mar. 3 Pittsburgh, Pa. Penn-Sheraton Hotel
Spring Meeting—OSA	Mar. 2-4 Pittsburgh, Pa. Pick-Roosevelt Hotel
Instrumentation for the Iron and Steel Industry—ISA	Mar. 8-10 Pittsburgh, Pa. Pick-Roosevelt Hotel
Annual Convention —ASP	Mar. 19-25 Washington, D. C. Shoreham Hotel
Internat'l Convention —IRE	Mar. 20-23 New York, N. Y. Coliseum and Waldorf-Astoria Hotel
Symposium on Temperature, Its Measurement and Control in Science and Industry—AIP, NBS, ISA	Mar. 27-31 Columbus, Ohio Veteran's Memorial Hall and Deshler-Hilton Hotel
Conference on Electro-Optical and Radiation Devices—IRE, AIEE	April San Jose, Calif.
Joint Automatic Techniques Conference—IRE, AIEE, ASME	April Cincinnati, Ohio
Progress in Electrical-Electronic Equipment Exhibit	Apr. 4-6 St. Louis, Mo. Kiel Auditorium
Annual Symposium, Electronic Process Instrumentation—ISA	April 4 Newark, N. J. Hotel Essex House
International Symposium on Electro-Magnetics and Fluid Dynamics of Gaseous Plasma—IRE, NS, IAS, Polytechnic Inst. Brooklyn, Dept. of Defense	Apr. 4-6 New York, N. Y. Eng. Soc. Bldg. Auditorium
Annual Meeting and Exposition—IES	Apr. 5-7 Washington, D. C. Sheraton-Park
Application of Continuous Analyzers to Process Control—AIChE	April 7 Marietta, Ohio
Federation of American Societies for Experimental Biology Meeting and Exhibit —FASEB	April 10-14 Atlantic City, N. J. Auditorium
Symposium on Biomedical Engineering —AIEE, IRE, San Diego Naval Hosp.	April 13, 14 San Diego, Calif.
National Symposium on Instrumental Methods of Analysis —ISA	Apr. 17-19 Houston, Texas Shamrock-Hilton
Southwestern IRE Conference and Show (SWIRECO) —IRE	Apr. 19-21 Dallas, Texas Memorial Aud. and Baker Hotel
Southeastern Regional Conference and Exhibit—ISA	Apr. 19-21 Charlotte, N. C. Park Center and Public Library

ELIMINATE MATHEMATICAL COMPUTATIONS...

W&T PRECISION MERCURIAL MANOMETERS

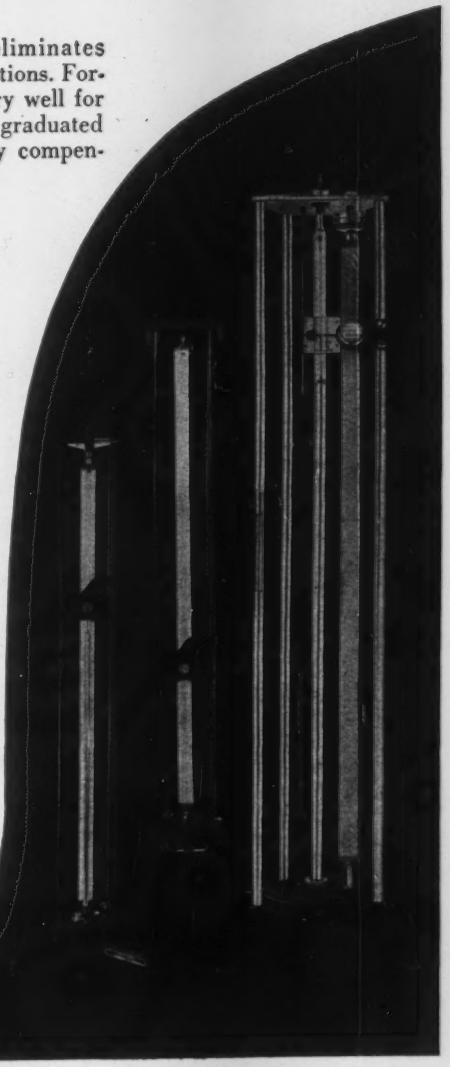
Simple knob adjustment eliminates temperature and gravity corrections. Forget about indexing the mercury well for each reading. W&T's specially graduated manometer scale automatically compensates for well level depression.

The Wallace & Tiernan FA-187 mercurial manometer also gives you:

- ★ Accuracy 1/5000
- ★ Range 0 to 31.5″ Hg or equivalent
- ★ Readings to 0.005″ Hg
- ★ Magnifying eye piece for exact reading
- ★ Magnetic vernier eliminates meniscus reading
- ★ Specially calibrated scale

Use the W&T mercurial manometers as calibrating standards for absolute pressure or easily modify them to perform as barometers, differential or vacuum indicators.

For further information, write Dept. A-128.48



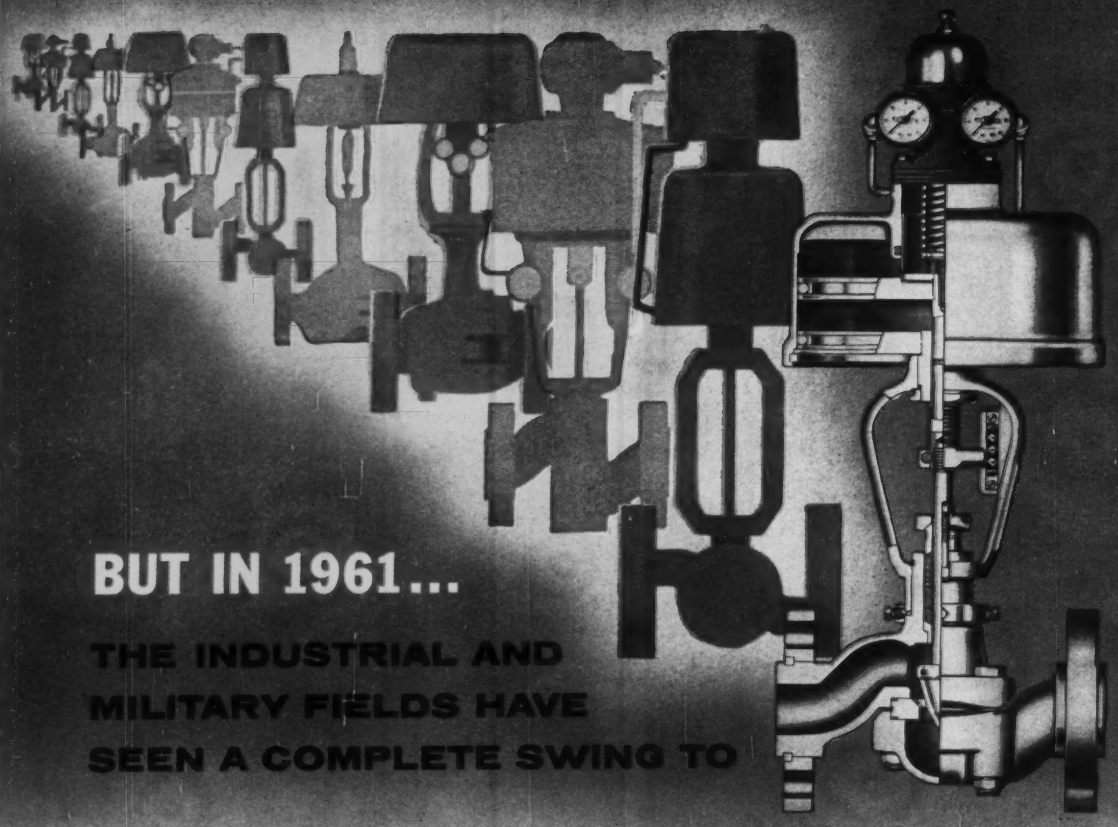
WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CIRCLE 26 ON READER-SERVICE CARD

IN 1948...THEY SAID IT COULDN'T BE DONE

...that split body, single seat construction would never be the accepted design for industrial or military control valves.



BUT IN 1961...

THE INDUSTRIAL AND MILITARY FIELDS HAVE SEEN A COMPLETE SWING TO

CONTROL the ANNIN WAY

In 1948 split body construction and powerful high speed, precise positioning pneumatic piston actuators were available from only one source—Annin. Today, more than a decade of accumulated experience in this type of valve design makes Annin features and performance records the best in the valve industry. Contrary to published statements by critics thirteen years ago, Annin-type construction is now available from many sources. But when tempted to consider *mere-replicas* of Annin valves, remember this—they might give you a few Annin features, but when you specify Annin Valves you get them all!

Annin VALVES

THE ANNIN COMPANY
1040 South Vail Avenue
Montebello, California

CIRCLE 27 ON READER-SERVICE CARD

Now! Get premium features in a DVM priced at only $940

Cubic Corporation announces the V-45 —the first low-cost digital voltmeter with premium features. Now industrial users can buy a top-quality, precision four-digit instrument at a price they can justify—only $940. Here are the premium features you get in a V-45:

Floating Input: Both sides of the input may be floated above or below ground. The floating input circuit provides more than 80 db rejection to 60-cps common-mode signals. A grounded input is also supplied.

Extended Range: A 10% extension is incorporated in each of the V-45's three ranges. Voltages up to 10.999 may be read on the 10-volt range; voltages up to 109.99 may be read on the 100-volt range; and voltages up to 1099.9 may be read on the 1000-volt range. Therefore, the operator need not constantly shift back and forth between ranges when reading close to the normal upper limit of a range.

Transistorized Logic and Drive Circuit: The V-45 DVM uses construction techniques representing the latest state-of-the-art, with all-transistorized circuitry driving reliable stepping switches.

Cubic manufactures a complete line of quality digital instruments, including a-c and d-c voltmeters, ohmmeters, ratiometers, scanners and printer controls. Write for literature to Dept. IC-101, Industrial Division, Cubic Corporation, San Diego 11, California.

SPECIFICATIONS

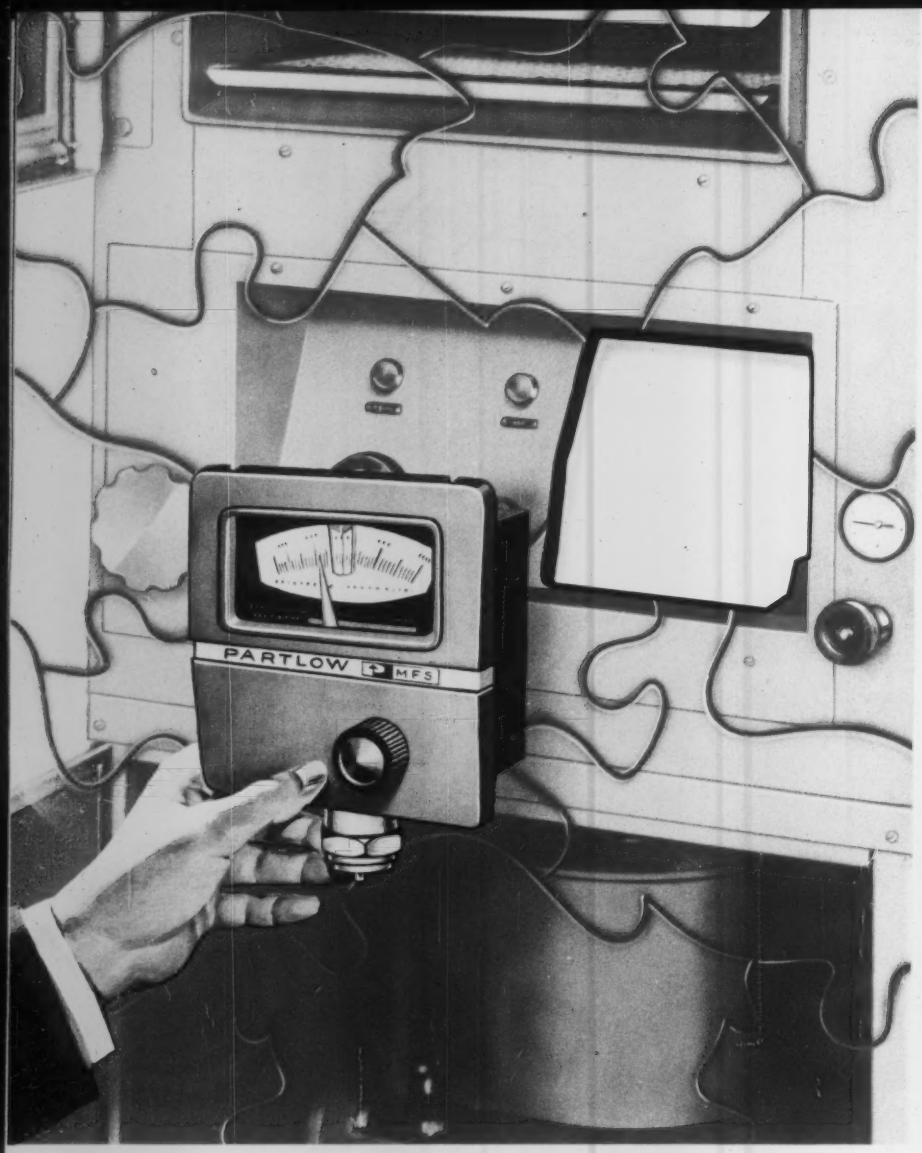
MODEL V-45 DIGITAL VOLTMETER

Input Impedance: 10 megohms at balance.
Ranges: Manually selected, 10% extended range
Low ±0.000 to ±10.999 vdc
Mid ±00.00 to ±109.99 vdc
High ±000.0 to ±1099.9 vdc
Sensitivity: 1 millivolt
Sensitivity Control: Continuously variable from 1 digit to standby lockout.
Power Input: 105-125 vac, 50-60 cps, 25 watts standby, 30 watts operating.
Dimensions: 19" wide, 5¼" high, 14" deep, rack or bench mounting with dust-proof switch and bridge section.
Average Balancing Time: Less than 2 sec.

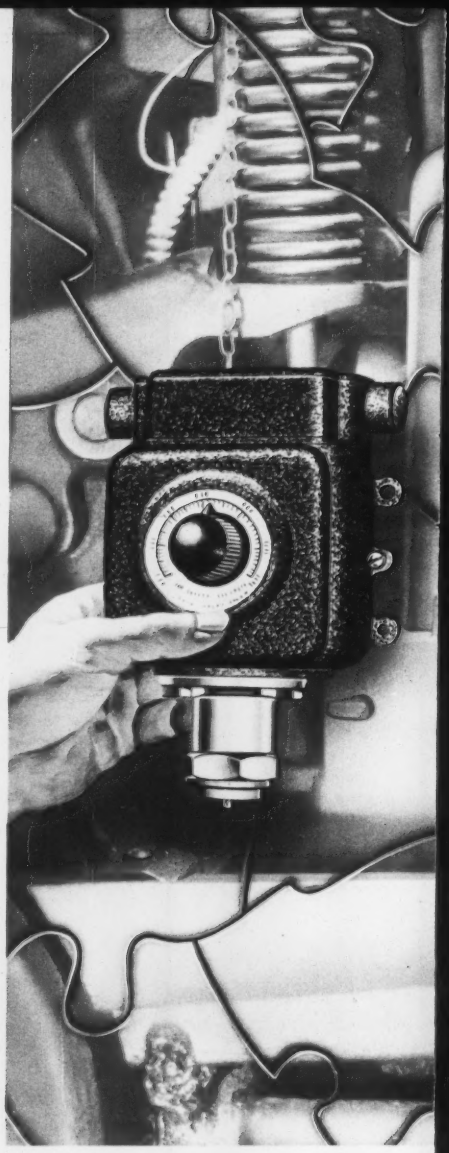
cubic CORPORATION

CIRCLE 28 ON READER-SERVICE CARD

CIRCLE 29 ON READER-SERVICE CARD ⟶



Partlow makes 25 different indicating control models, including the handsome, high-visibility MFS shown here.



Partlow non-indicating controls give maximum dependability at minimum cost.

A Perfect Fit for Any Temperature Control Application!

Partlow temperature controls today function in an almost infinite range of industrial processes . . . Economically. Accurately. *Precisely!*

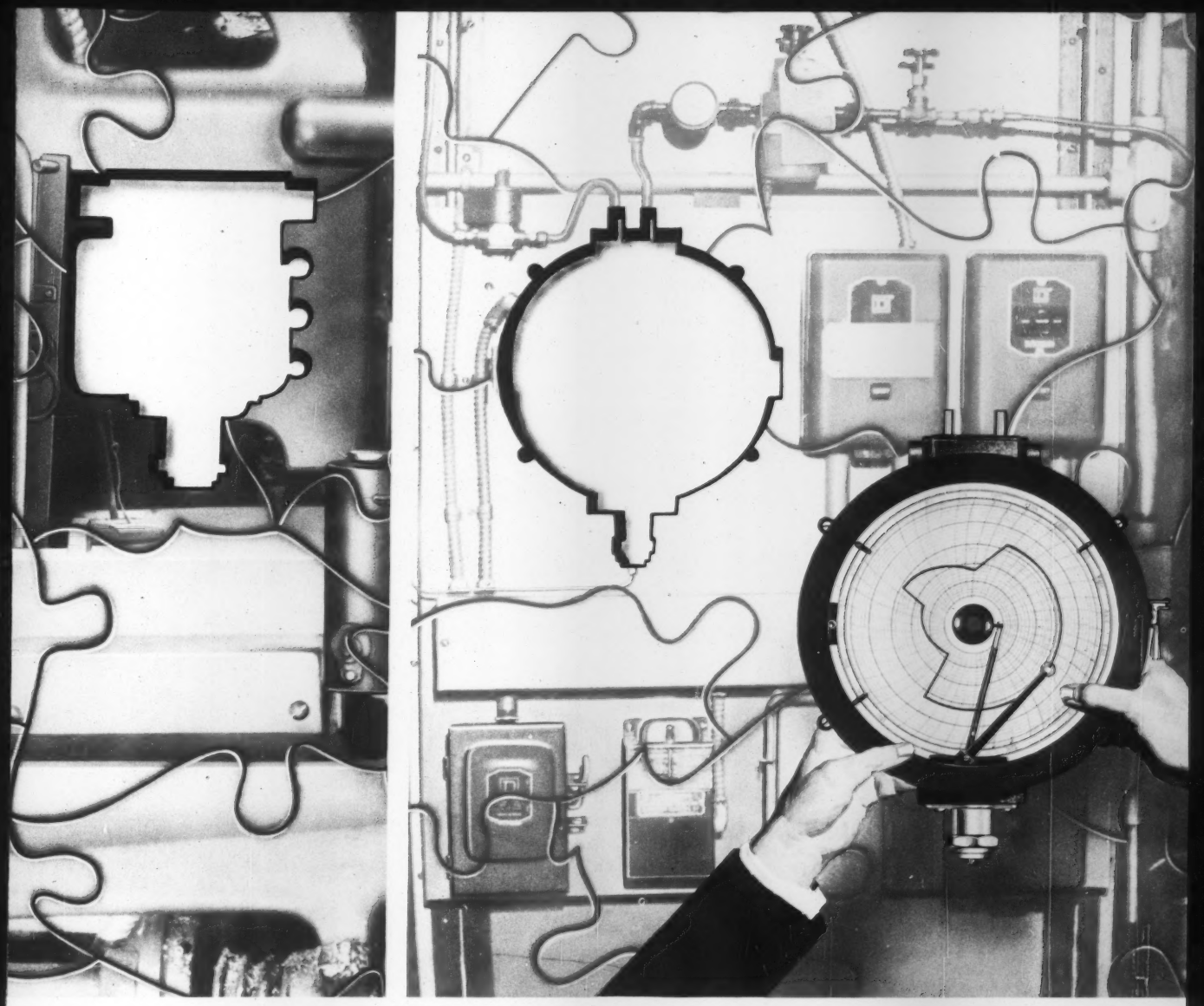
They can perform just as efficiently for *you*.

Partlow controls are actuated by the direct, positive power of mercury, require no mechanical or electronic amplification. Regardless of type, any Partlow you install will stand up to even extreme conditions of shock and vibration . . . without loss of accuracy or sensitivity.

And Partlow makes service headaches a thing of the past! All it takes to replace the Partlow thermal element is a wrench or screwdriver. No 'down time' necessary! The whole job can be done, right at the work site, in a matter of minutes.

If you need accurate, dependable temperature control anywhere within the −70° to 1100°F. range, you'll find a Partlow model to fit your requirements *exactly*.

Get full details without obligation. Fill out and mail the coupon now.



Versatile Partlow recording instruments keep rigid control of process temperatures, and prove it in writing.

Partlow makes the following types of controls and allied equipment for temperatures ranging from −70° F. to 1100° F.:

- Electric
- Mechanical
- Pneumatic
- Indicating
- Non-Indicating
- Recording
- Explosion-Proof
- Weather-Resistant
- Limit
- Program
- Multi-Switch
- Double Pen Recording
- Process Timers
- Safety Equipment
- Thermometers
- Control Accessories

41 Partlow Sales and Service Offices in Principal Cities of the United States, and the World.

World Export: Ad Auriema Inc., 85 Broad Street, New York 4, N.Y., U.S.A.

PARTLOW

TEMPERATURE CONTROLS

THE PARTLOW CORPORATION

New Hartford, N.Y., Dept. B

Please send condensed Catalog of Partlow temperature controls and allied equipment for industrial heating and refrigeration.

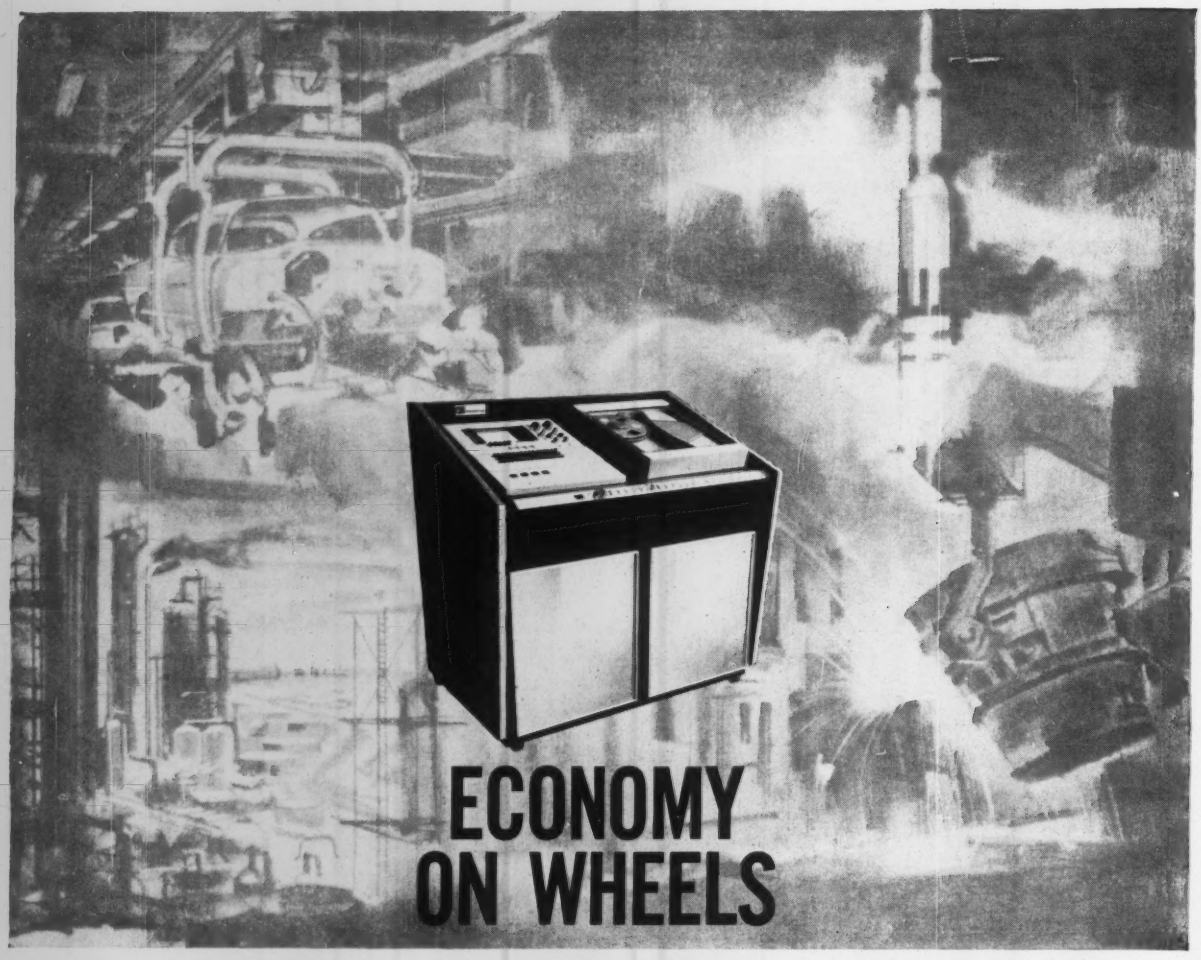
Name and Title.....

Company.....

Address.....

City and State.....

.....



With RADATAC I, Radiation's portable, low cost data acquisition system

Selecting data from low-level analog pick-offs and putting them into the *right* format for entry into a digital computer is frequently the most costly step in a performance evaluation program. RADATAC I (Radiation's Data Acquisition Cart) permits you to take this step directly and rapidly—eliminating much expensive data processing equipment and appreciably reducing computer time.

RADATAC I combines Radiation's Radicon analog/digital converter, Radiplex low-level electronic commutator, and an Ampex tape recorder (with the necessary logic circuitry and power supplies) into a single mobile unit. The system handles up to 48 analog inputs from resistive or thermocouple sources (as low as ± 5 mv full scale) with a resolution of ± 10 μv. After digital conversion, the information is recorded in computer format on magnetic tape. Data formats are available which are directly compatible with most large and medium scale digital computers.

For more complete data on RADATAC I, write to Dept. IC-2R, Radiation Incorporated, Products Division, Melbourne, Florida.

THE ELECTRONICS INDUSTRY ALSO RELIES ON RADIATION FOR...

RADIPLEX 89 – a 48-channel low-level multiplexer with broad data processing applications. Features rugged solid-state circuitry, almost unlimited programming flexibility, unique modular construction for compactness and exceptional ease of operation and maintenance.

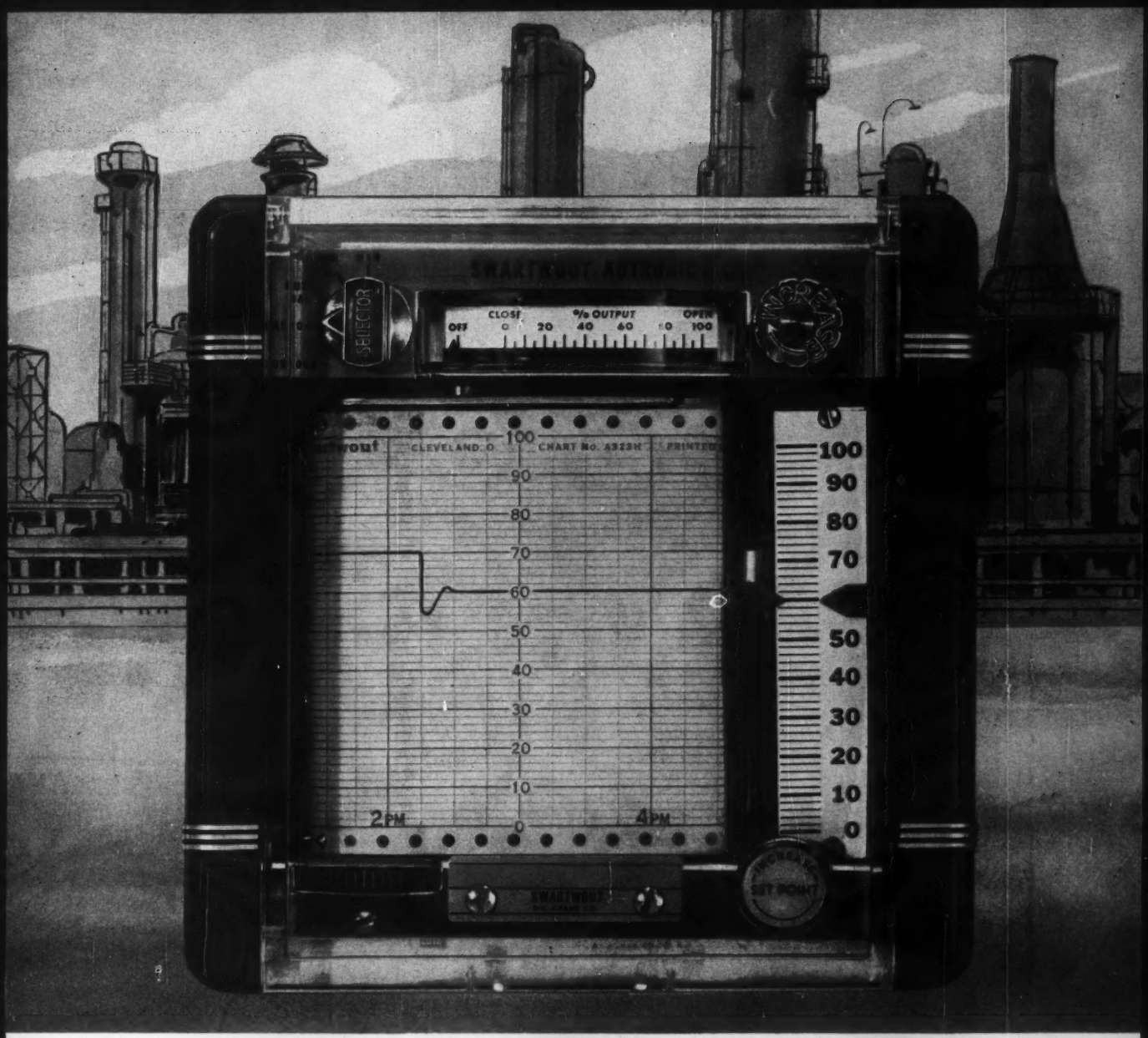
RADICORDER – Multistylus recorder provides high-speed instantaneous readout for wide range of data acquisition or processing systems. Eliminates necessity of electronically translating complete data, thereby reduces computer work loads.

TDMS – Telegraph Distortion Monitoring System pinpoints type and source of trouble on teletype, data processing and similar communications links without interrupting traffic. Ultra-compact TDMS can replace most test equipment now required for teletype maintenance and monitoring.

RADIATION INCORPORATED

CIRCLE 30 ON READER-SERVICE CARD

←— CIRCLE 29 ON READER-SERVICE CARD



THERE IS NO SUBSTITUTE

FOR SUCCESSFUL *ELECTRONIC* CONTROL EXPERIENCE

Ten years ago, on the basis of guardedly optimistic lab reports and some reassuring field tests, Swartwout sold industry's first fully-electronic process control system.

The rest is case history. 654 million on-stream hours later, with some 20,000 Autronic loops in the field, Swartwout can offer you electronic control experience not available from any other source.

Swartwout engineers started with a clean slate and their own chalk. Autronic® equipment was developed for electronic systems, not adapted to them. Swartwout people think electronic control and understand its application as only specialists can.

With Swartwout Autronic control equipment, you get the type of experience that avoids many pitfalls, virtually guarantees the success of your electronic control system.

Write for Bulletin A-913.

SWARTWOUT

SWARTWOUT DIVISION, CRANE CO.

HOOKSETT INDUSTRIAL PARK • MANCHESTER, NEW HAMPSHIRE

SWARTWOUT . . . World Leader in Electronic Process Control

moving fast with CRANE

CIRCLE 31 ON READER-SERVICE CARD

Typical control panel at Union Carbide's Institute Plant has over 100 Foxboro Consotrol* indicators, recorders, and controllers.

for Union Carbide's Institute Plant...rapid,

A sprawling chemical metropolis, stretching as far as the eye can see. That's Union Carbide Chemicals Company's Institute, West Virginia plant — producer of Ucon† Fluorocarbon propellants and refrigerants.

Foxboro instrumentation is used to help control 20 of the different processing units at the Institute Plant. Over 10,000 Foxboro indicators, controllers, recorders, and transmitters are used, as well as thousands of Foxboro control valves.

Union Carbide reports favorably on their Foxboro instruments. "In general, we find them easy to work on, easy to repair, easy to maintain." And the company adds, "we appreciate the ability of the Foxboro engineers who work with us."

*Reg. U. S. Pat. Off.
† Trade-mark of Union Carbide Corp.

CIRCLE 22 ON READER-SERVICE CARD

Process is hydraulic — requires fast, sensitive instrument response.

sensitive Foxboro control

You'll like working with Foxboro, too. Unsurpassed instrumentation, both pneumatic and electronic; unsurpassed engineering and service. Ask your local Foxboro Field Engineer for the complete story. Or write for Bulletin 13-18. The Foxboro Company, 462 Norfolk Street, Foxboro, Massachusetts.

Lab analysis is done right in the control room of this Carbide processing unit. Necessary process adjustments can be made on Foxboro controllers the minute technician detects the need.

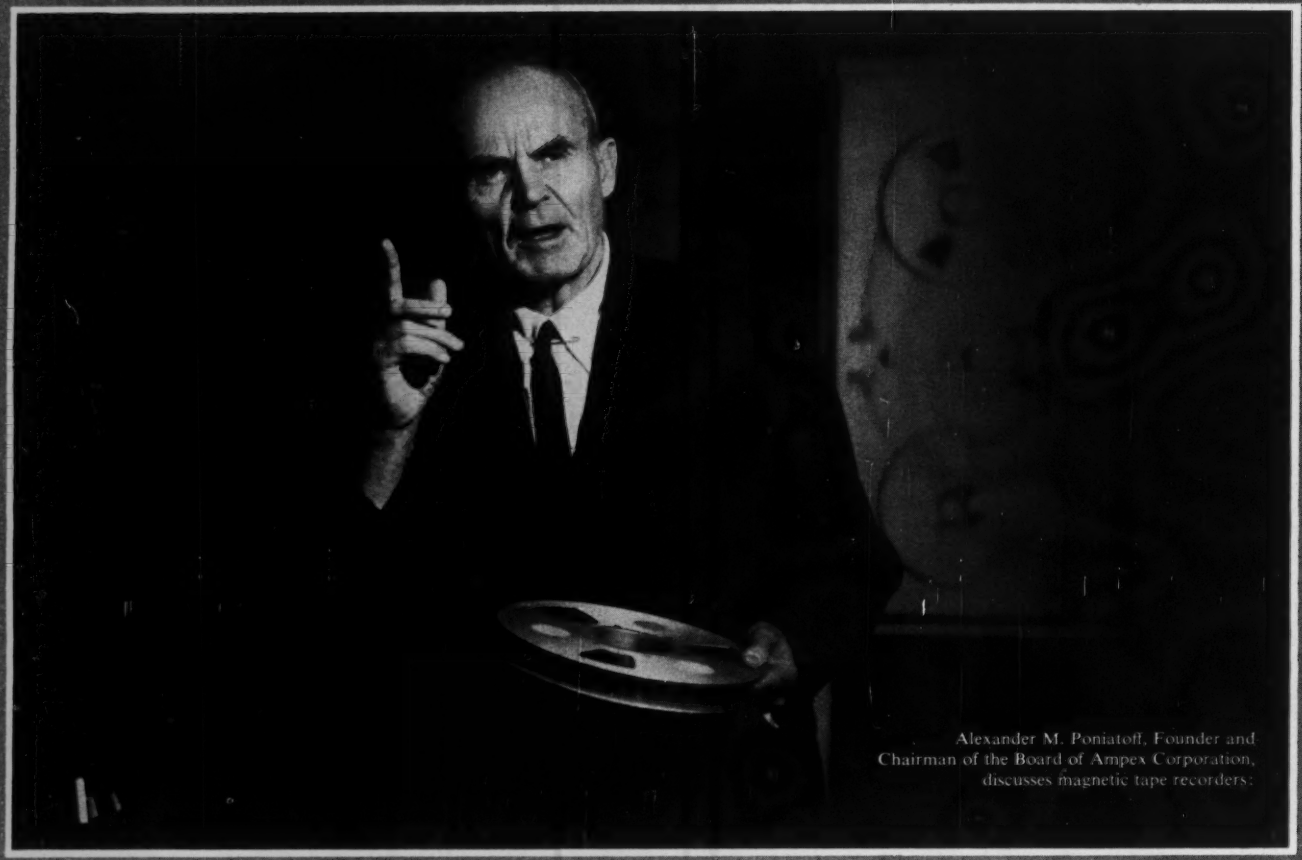
FOXBORO

REG. U.S. PAT. OFF.

CIRCLE 32 ON READER-SERVICE CARD

Constructive discontent at Ampex...

. . . has been setting instrumentation standards for years



Alexander M. Poniatoff, Founder and Chairman of the Board of Ampex Corporation, discusses magnetic tape recorders.

"Everything Ampex recorders stand for – service, quality, reliability, technological leadership – stems from this attitude.

"The first commercial 'live-quality' audio recorder was developed by Ampex because of the disc record's fidelity drawbacks. Discontent with the capabilities of all data recorders using visual traces spurred Ampex's evolution of special purpose magnetic tape data recorders. Frequency limitations bothered us, so we gave you the 4-megacycle FR-700.

"A need for compact equipment with high performance caused us to introduce the CP-100 – a transistorized 200 kc 14-track data recorder less than 7 cu. ft. small. Striving for versatility and high efficiency, we perfected the FR-600; it records 500 kc at 120 ips – double the previous standard, but still fully compatible.

"And we were even constructively discontented with the way we made these advanced recorders available to you. Now, Ampex instrumentation recorders can be leased or purchased on time as well as outright. You can free working capital for other projects, and invest in your Ampex data recorder as it works for you."

Some significant specifications:

AR-300, FR-700: 10 cps to 4 mc ±3 db; 12½ and 25 ips record and playback. FM recording. Two data, two auxiliary tracks. 2″ tape, 10½″ reels. AR-300 airborne record only.

CP-100: 300 cps to 200 kc ±3 db at 60 ips; 60, 30, 15, 7½, 3¾, 1⅞ ips with proportional response. Direct or FM recording. All-transistorized. ½″ or 1″ tape, 10½″ reels.

FR-600: 300 cps to 500 kc ±3 db at 120 ips; 60, 30, 15, 7½, 3¾, 1⅞ ips with proportional response. Direct, PDM or FM recording by plug-in modules. ½″ or 1″ tape, 10½″ or 14″ reels.

For detailed information on the complete Ampex line of data recorders, write:

AMPEX INSTRUMENTATION PRODUCTS COMPANY

Box 5000, Redwood City, California

AMPEX

Experienced engineers eager to contribute to Ampex's pioneering reputation are invited to write the Manager, Technical Recruiting.

AE

TO THE ENGINEER

looking for an airtight case

Need relays or stepping switches that will stay fresh as daisies—even in environments of high humidity, gritty dust, or extremes of temperature or pressure? *You can get them*, securely housed in ideal atmospheres of their own.

AE makes an airtight case out of every job by completely evacuating the prewired assembly, replacing the air with a dry, inert gas to a pressure of at least one atmosphere, and tightly sealing the housing. Then we test it, and if there's a single, tiny leak—enough to pass 1 cc of air in 30 years—we reject the assembly! Here's real protection from adverse environmental conditions (from tampering, too).

Ask for AE's Catalog 4083 on Hermetically Sealed Enclosures. It shows the wide variety of housing sizes and shapes available—with hook terminals, socket or cable plug-ins, or special printed-circuit connectors. Into these housings AE will put relays and switches assembled and wired to your specifications—or we will design and deliver complete control packages or systems. Chances are we can do the job at less cost, too.

If you have a sticky control problem, just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. *In Canada:* Automatic Electric Sales (Canada) Ltd., 185 Bartley Drive, Toronto 16, Ontario.

AE CAN DO

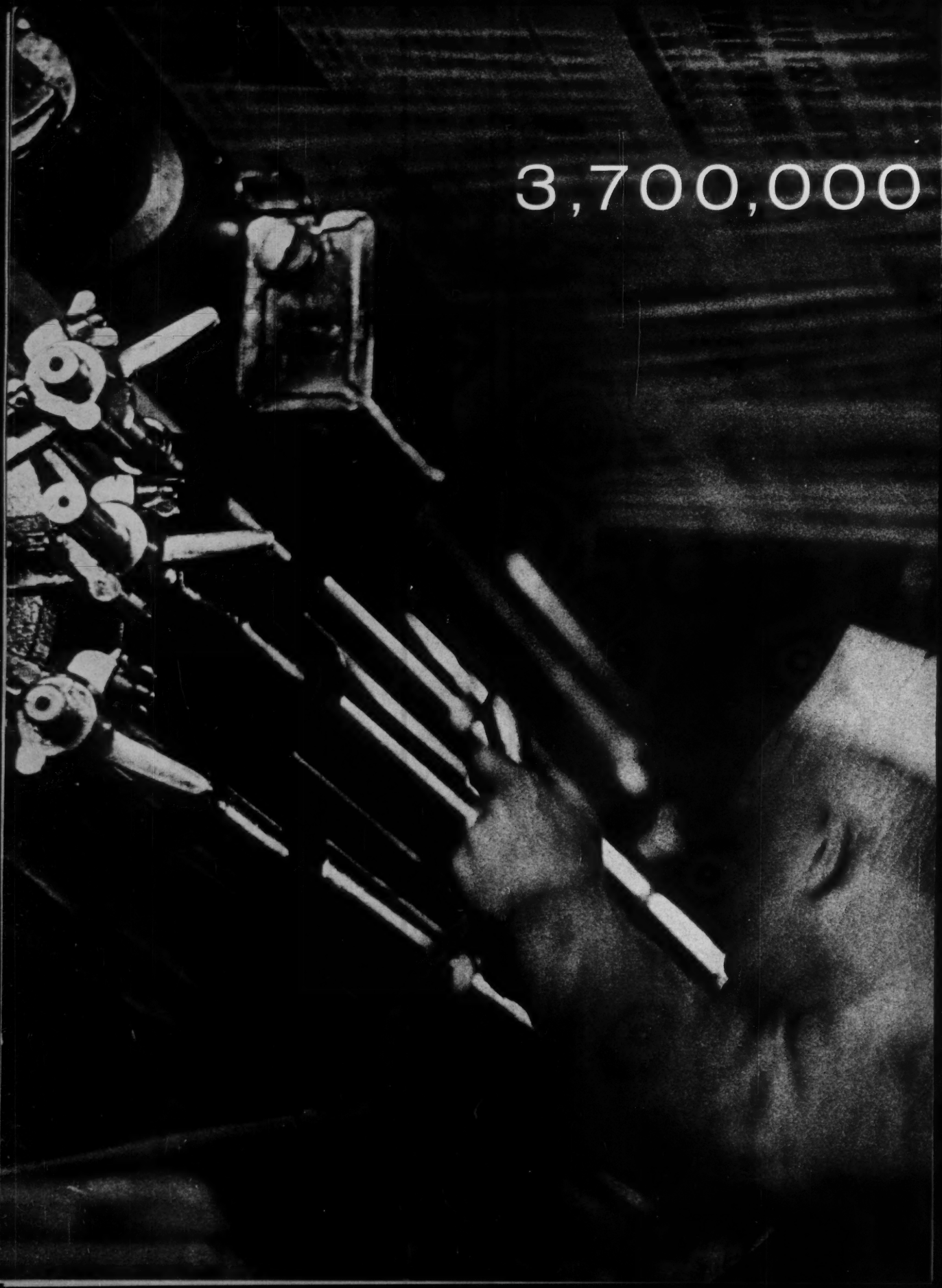
AUTOMATIC ELECTRIC GENERAL SYSTEM

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

CIRCLE 34 ON READER-SERVICE CARD

←CIRCLE 33 ON READER-SERVICE CARD


3,700,000

WORDS A DAY...

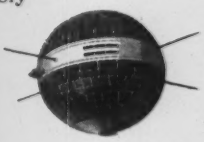
or more words than are teletyped every day by every wire service in the U. S.

This gives you some idea of the capacity of the new 500-pound Courier teletype satellite now orbiting the earth 14 times a day, 600 miles up.

Heart of the U. S. Army Courier system is a cluster of five five-pound magnetic tape recorder/reproducers made by Consolidated Electrodynamics. Four of them store and transmit teletyped messages. The other carries analog or voice messages.

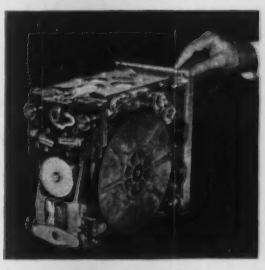
Each CEC unit is programmed separately and has the capacity to record 55,000 data-bits per second, for five minutes on one channel, at a tape speed of 30 inches per second. After recording, the tape drive is reversed by command from the ground to reproduce the signal backwards.

The Courier satellite project is obviously important to our current defense effort. Less obvious, yet more important to us and our children, is its far-reaching implication of world-wide ground-space-ground communications. When a phone call to Antarctica will be as simple as one to your next door neighbor.



Why did the Department of Defense choose CEC for this delicate and far-reaching assignment? Experience, mostly. And imagination. They didn't ask "Can it be done?" They said, ***"Do it."***

And the company that (1) records 90% of *all* Atlantic-range missile-test flights, (2) went down with the Nautilus using mass spectrometers to test air contaminants, (3) went up with the B-58 to flight test the world's fastest bomber, (4) went higher with a satellite-carrying spectrometer to measure radiation, (5) designed "Micro-plant"—first unattended petroleum pilot plant, and (6) monitors, measures, analyses, controls and records almost anything for industry and defense ***did it.***



CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

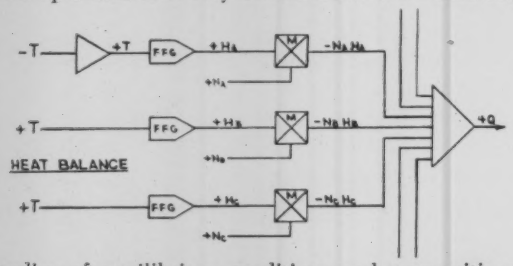
DATA RECORDERS DIVISION • DATALAB DIVISION • TRANSDUCER DIVISION
ANALYTICAL & CONTROL DIVISION • CONSOLIDATED SYSTEMS CORPORATION
CONSOLIDATED VACUUM CORPORATION

A SUBSIDIARY OF **Bell & Howell** • *FINER PRODUCTS THROUGH IMAGINATION*

CIRCLE 35 ON READER-SERVICE CARD

Chemical Equilibrium Simulation

In chemical process development it is often desirable to evaluate equilibrium conditions and composition as affected by system heat input. These evaluations help optimize such variables as feed temperature and operating pressure. The analog computer with repetitive operation is a very effective tool for conducting



studies of equilibrium conditions and compositions. The example at hand considers a common complex chemical equilibrium determination.

In a complex chemical system wherein the heats of reaction, heat contents, equilibrium constants, and feed composition are known, it is desirable to determine equilibrium temperature and composition. A system in which two reactions occur, has been chosen for demonstration of this problem solution.

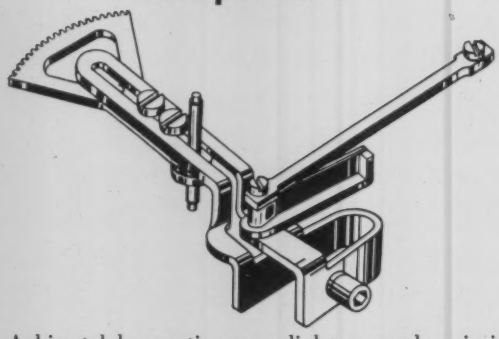
Reaction (a) $A + B \rightleftarrows C$

Reaction (b) $C \rightleftarrows D + E$ . . .

(*From 9-page Report Form 80-105-008 describing application of new Dystac dynamic storage analog computer to determination of complex chemical equilibrium conditions and composition, Computer Systems, Inc., Culver Rd., Monmouth Junction, N. J.*)

FOR THIS LITERATURE CIRCLE 201 ON READER-SERVICE CARD

Bourdon Tube Thermal Compensator



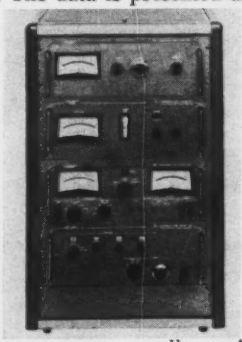
A bimetal bar, acting as a linkage member, is incorporated in such a way that its deflection, resulting from ambient temperature changes, is proportional to corresponding changes in other gauge members. This completely compensates for thermal expansion and contraction of linkage parts as well as for thermal variation in the Young's Modulus of the Bourdon tube . . . (*From 16-page catalog including principle and history of Bourdon Tubes as well as design features and developments, Heise Bourdon Tube Co., Brook Rd., Newton, Conn*).

FOR THIS LITERATURE CIRCLE 202 ON READER-SERVICE CARD

I&CS BRIEFS

Transfer Function Analyzer

The Model 711 Transfer Function Analyzer measures the frequency response (Output/Input) of an item under test . . . over a frequency range from .01 cps to 200 cps. The data is presented as In-Phase and



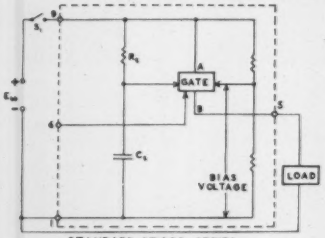
Quadrative Components as well as Amplitude and Phase. Noise on the return signal from the item under test is attenuated by 40 db.

The primary advantages . . . wide frequency range, fast readout on low frequency ranges, high noise rejection, accuracy (.25 db, 2°), chopper stabilized amplifier construction for low drift and minimum adjustments . . .

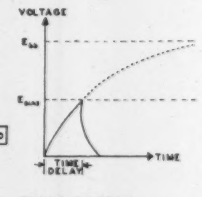
The Model 711 . . . is built on a Modular Basis . . .: Low Frequency Signal Generator, Return Signal Analyzer, Phase & Amplitude Computer, Timing Interval Reader, Power Supply . . . (*From 18-page Bulletin 711, Boonshaft and Fuchs, Inc., Hatboro Industrial Park, Hatboro, Pa.*)

FOR THIS LITERATURE CIRCLE 203 ON READER-SERVICE CARD

Fixed Time Modules



STANDARD ST1000 SERIES

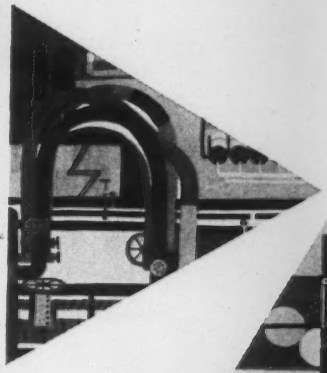


TIMING DIAGRAM

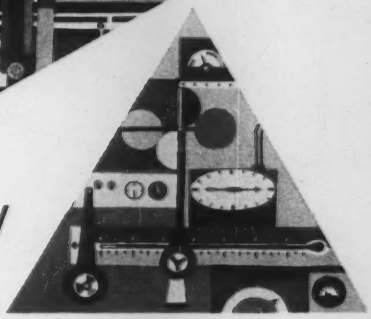
The operation of the basic timing module is as follows: The module consists of an RC timing network, resistance divider, gate and load . . . the load is connected between the gate and ground. In some cases, however, it is connected between the gate and supply voltage depending upon whether the output transistor is NPN or PNP. Closure of switch S_1 immediately establishes a bias on the gate circuit. At the same time, capacitor C_t begins to charge through the timing resistor R_t. When the voltage across the timing capacitor reaches the bias voltage, the gate fires and a step voltage appears across the load . . . (*From 14-page Bulletin 5906, Tempo Instrument Inc., Commercial St., Box 338, Hicksville, N. Y.*)

FOR THIS LITERATURE CIRCLE 204 ON READER-SERVICE CARD

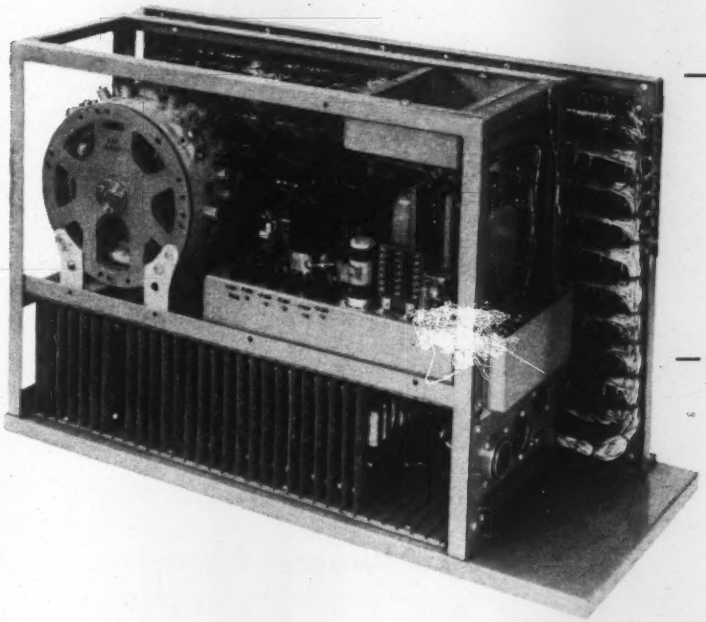
now from **Clary**

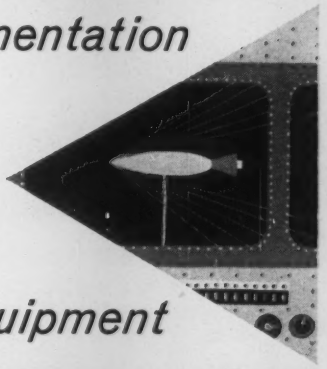


a digital arithmetic center that works with: *–process control*

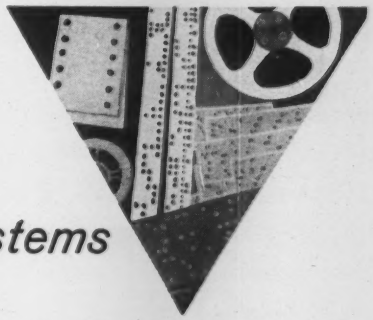


–instrumentation





–test equipment



–data-processing systems

Important specifications include:

Number System... Decimal
Word Length... 18 decimal digits and sign
Storage... Magnetic Drum
Storage Capacity... 16 words per channel, non volatile
10 channels are available
2 channels are supplied as standard equipment
Instructions... Multiple Address
Input of Data... Unique pulse per digit or binary coded decimal
Input of Instructions... DC voltage to proper connector pin(s)
Output... Unique pulse per digit or binary coded decimal
Size... Length 28", height 19", width 13"
Weight... 97 lbs.
Power... 117 VAC ±10%, 150 watts maximum, 60 cycle, single phase
Construction... Modularized, solid state, plug in components

You name the application, and Clary's new arithmetic center—the DAC-2500—will fit it.

FLEXIBLE. This unit performs arithmetic, logical, and memory functions with electronic speed and accuracy . . . works with punch card and tape devices, analog to digital converters, X-Y plotters, printers, and other input and output equipment.

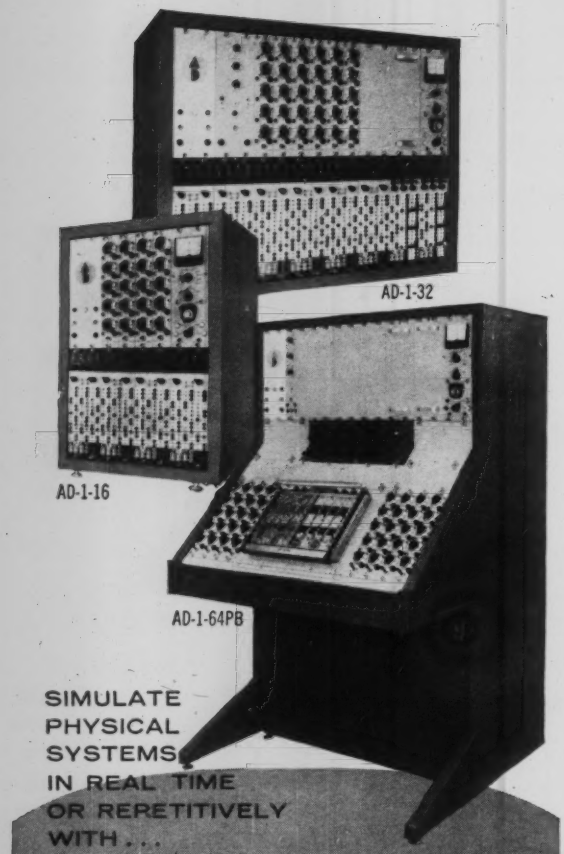
PROVEN. This is an off-the-shelf item. It has been proven in actual applications. Production-line quality makes it low-in-cost, insures prompt delivery, reduces maintenance and repair problems.

RELIABLE. Clary's long experience in quality controls and the use of solid state electronics insure exceptional reliability.

For information on how you can use the DAC-2500, write direct for Engineering bulletin SS-4.

Clary CORPORATION,
COMPUTER DIVISION
San Gabriel, California

CIRCLE 36 ON READER-SERVICE CARD



SIMULATE PHYSICAL SYSTEMS IN REAL TIME OR REPETITIVELY WITH . . .

Applied Dynamics Analog Computers SERIES **AD-1**

Modular Design For Plug-in Expandability And Maximum Reliability

- Passive-circuit diode multipliers and function generators
- Computing resistors matched to .01%
- Repetitive operation with electronic reset and simultaneous real-time operation
- Continuous overload monitoring and integral balance check system

AD-1 Series analog computers are available with from 4 to 64 amplifiers for solution of various types of linear and non-linear equations.

The AD-1-64PB features a removable preprogrammed patchboard with up to 64 stabilized amplifiers, 80 coefficient potentiometers, 16 multipliers, 8 function generators, and 20 diode networks.

The AD-1-32 and AD-1-16 feature a fixed patchboard system with up to 32 and 16 amplifier capacity and non-linear equipment for maximum economy.

Modular design permits flexible arrangements to suit various operating requirements.

Applied Dynamics, Inc.

A Subsidiary of Bowmar Instrument Corp.

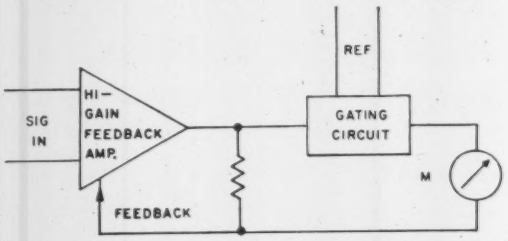
ANN ARBOR, MICHIGAN

Specialists in Industrial and Process Instrumentation and Controls

CIRCLE 37 ON READER-SERVICE CARD

Phase Sensitive VTVM's

All the AC instruments described in the AC section of Trio Catalog 59-110B (with the exception of Model 120-1) can be made phase sensitive . . . by using a zero-center indicating meter and by providing access for an external reference voltage to gate a modified diode detector bridge . . . The crux of the operation of the phase sensitive circuit is the technique employed in the diode bridge . . . The input signal is



fed through input stages which establish the proper attenuation ratio and input impedance, then to a hi-gain amplifier section. The output of the amplifier is fed to the gating circuit which is essentially a modified diode detector bridge. The reference voltage actually controls the gating or switching action of the gating circuit. The gating circuit and meter are parallel with the resistor in the feedback path, shown in the simplified schematic. During one half of its cycle, the reference voltage causes the gating circuit-meter path to be effectively an open circuit so that the full signal passes through the resistor . . . During the other half cycle of the reference voltage, the gating circuit offers a low impedance path (compared to the resistor path) causing current flow through the gating circuit and meter. The meter, then, indicates only during this half cycle of the reference voltage . . . (*From* 34-*page Catalog* 59-110*B, TrioLabs, Inc., Plainview, L.I., N.Y.*)

FOR THIS LITERATURE CIRCLE 205 ON READER-SERVICE CARD

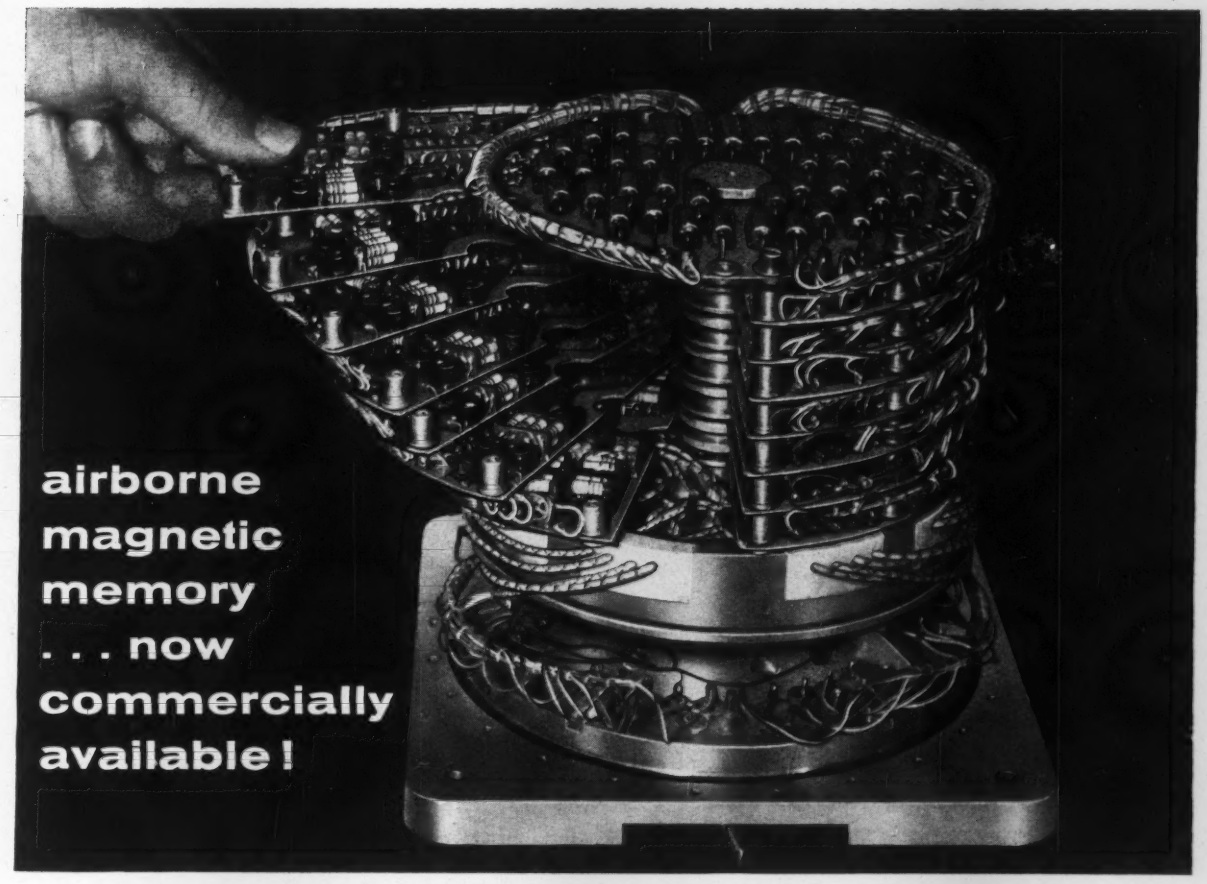
Linde Alumina Abrasives

PHYSICAL PROPERTIES

	Type A–5175	*Type B–5125*	*Type C–5250*
Chemical Formula	Al_2O_3 (Alpha)	Al_2O_3 (Gamma)	Al_2O_3 (Alpha)
Crystal System	Hexagonal	Cubic	Hexagonal
Hardness, Mohs'	9	8	9
Particle Size, approximate (microns)	0.3	<0.1	1.0
Apparent Density (g/c.c)	0.3–0.6	0.2–0.5	0.3–0.6
Melting Point	2050°C.	Transforms to Alpha form at high temperatures	2050°C.
Specific Heat at 25°C	0.18	—	0.18

Linde alumina abrasives are white powders of at least 99.9% purity. They are highly resistant to attacks by common acids. They are notably characterized by extremely uniform ultimate particle size, which obviates the necessity for levigation in sharpening, honing or polishing work. Type A and C remove stock faster than Type B, but Type B produces a superior finish. Depending upon the application, these abrasives may be used dry or mixed with water or other vehicles to make a thin slurry or heavy paste. They have also been compounded with waxes to provide a convenient stick form . . . (*From* 2-*page bulletin, also* 4-*page reprint, "A Universal Polishing Method," Linde Co., Div. Union Carbide Corp.,* 30 *E.* 42 *St., New York* 17, *N. Y.*)

FOR THIS LITERATURE CIRCLE 206 ON READER-SERVICE CARD



New LFE Bernoulli Disk Data Storage Device weighs 6 pounds* . . . operates on 12 watts . . . resists 30g shock!

Originally developed for reliable storage and retrieval of data in outer space, this miniaturized unit introduces the BD-40 Series of customized LFE Bernoulli Magnetic Disk Memories . . . the simplest rotating storage devices ever developed.

These space-and-weight-saving units store data on a flexible magnetic disk. Their read/write accuracy under extreme shock and vibration conditions is maintained by a balance of forces generated by fluid flow together with centrifugal and curvature forces in the disk.

Compatible with all EDP systems requiring storage of information on a magnetic surface, the BD-40 Series combines the advantages of minimum size, weight, and power with ultimate reliability and immunity to adverse operating environments. Available with or without electronic circuits. For complete information, write for Technical Data Brochure.

TYPICAL SPECIFICATIONS BD-40 SERIES	
Dimensions — Inches	
Height	4
With Electronics	7
Mounting Flange	7.25 x 7.25
Weight — Pounds	
*Without Electronic Package	6
With Electronic Package	10
Power Requirements — Watts (approx.)	
Motor Drive (115v, 400 cps, 3 phase)	12
Electronics (+5, −5, +10, +15v D.C.)	3 non-recording
Environmental	
Temperature-operating	0° to 85°C
non operating	−60° to 125°C
Shock	30g pulse
Vibration 5 to 27.5 cps	±1.3g
27.5 to 52 cps	0.036 in.
52 to 500 cps	±5g
Capacity — (Nominal) — bits	40,000
Data Storage Tracks	32
Adjustable Registers	4
Clock and Timing Tracks	4

LFE
COMPUTER PRODUCTS DIVISION

See a demonstration. 1961 IRE Show. Booths 3819-3821

LABORATORY FOR ELECTRONICS, INC.

1079 COMMONWEALTH AVE. • BOSTON 15, MASSACHUSETTS

CIRCLE 38 ON READER-SERVICE CARD

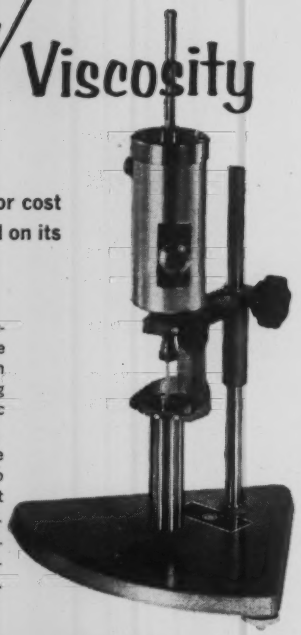
Rheology/ **Viscosity**

Does the quality or cost of your product depend on its flow characteristics?

► A complete line of Epprecht Viscometers provide viscosity measurements in the laboratory or during processing with automatic control of viscosity.

► Measurements can be made at pressures up to 700 psi or in a vacuum at temperatures to 300° C.

For detailed technical information on Epprecht Viscometers write to Dept. DV-28.



J. W. FECKER DIVISION
AMERICAN OPTICAL COMPANY

6592 HAMILTON AVENUE • PITTSBURGH 6, PENNSYLVANIA

CIRCLE 39 ON READER-SERVICE CARD

JEWELS *for*
INDUSTRY. . .

By MOSER JEWEL COMPANY, pioneer industrial jewel manufacturer for over 50 years.

- HIGHLY POLISHED STEEL PIVOTS AND STAFFS
- HARD ALLOY WELDED TIPS
- NON-MAGNETIC STAFFS
- DIAMOND POINTS

FOR INFORMATION ON HOW WE MAY FILL YOUR REQUIREMENTS

Write to . . .

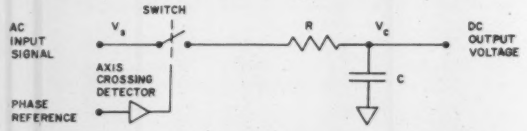
MOSER JEWEL COMPANY
P.O. Box 150 • Perth Amboy, N. J.

"Manufacturers of all types of Industrial Jewels"

CIRCLE 40 ON READER-SERVICE CARD

AC to DC Conversion

A new AC to DC conversion method developed by Adage, Inc., combines high degrees of accuracy, reliability, and speed with long-term stability . . . It is essentially an "averaging" technique (normally

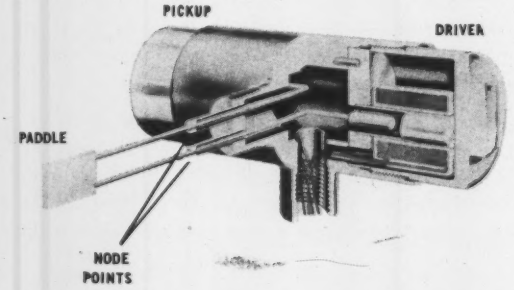


calibrated to read rms) which provides flexible choice of either self-synchronous or phase sensitive measurement of the a-c signal . . . The essential mode of operation is illustrated by the idealized diagram. The input signal is connected through a switch to an RC averaging network. The voltage on the capacitor represents the output of the device. The switch is opened and closed by the output of the axis crossing detector. The input to the axis crossing detector is the phase reference for the measurement. To accomplish self-synchronous measurement, the input signal itself is connected to the phase reference input terminal . . . (*From* 4-*page "Applications Notes on AC to DC Conversion," Adage, Inc.,* 292 *Main St., Cambridge* 42, *Mass.*)

FOR THIS LITERATURE CIRCLE 207 ON READER-SERVICE CARD

Dynatrol Viscometer

A detector consists of a driver end connected through a vibrational path to a paddle and returning to a pickup end—thus completing a loop through the controlled product. The driver coil receives a 60 cycle input and in turn produces a 120 cycle vibration in the loop . . . through an all-welded pressure seal . . . at node points where zero amplitude of vibration occurs.



The pickup end contains a permanent magnet and coil which gives an output signal proportional to the amplitude of paddle vibration. The EMF of this output signal is nominally at .5 volts.

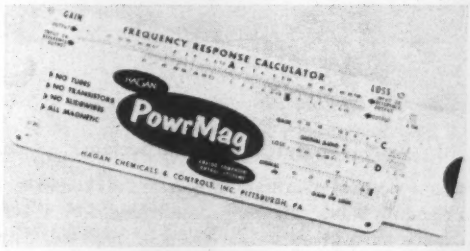
The paddle's amplitude of vibration and likewise the output signal reflect properties of the media surrounding the paddle. The development of this basic principle has provided a standard line of detectors . . . and receivers which adapt detector signals to the control of On-Off or Proportional devices . . . for control of Level, Interface, Density, Viscosity, and % Concentration. (*From* 4-*page Bulletin* 159, *Automation Products, Inc.,* 3030 *Maxroy, Houston* 24, *Texas.*)

FOR THIS LITERATURE CIRCLE 208 ON READER-SERVICE CARD

BRIEFS

Frequency Response Calculator

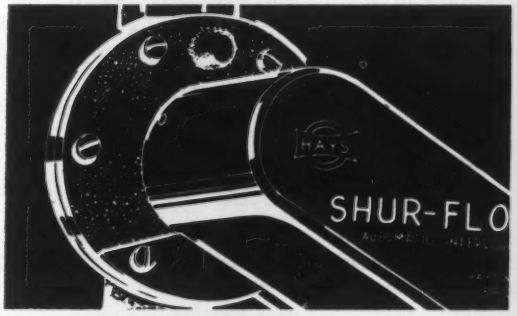
The pocket-sized "Frequency Response Calculator" eliminates the need for slide-rule computations or complex chart references when plotting a frequency response curve as a means of evaluating an amplifier, controller, transducer, power positioner, or other control device.



By using the Calculator, it is possible to rapidly convert the input-output relation of a component into the decibels of attenuation or gain occurring at a given frequency, and thus determine one point of the frequency response characteristic curve . . . In addition, the Calculator may be used to interpret frequency response curves. By taking any point off a frequency response curve, plotted in frequency gain in decibels, it is possible to read the ratio of input to output . . . (*From 2-page bulletin, Hagan Chemicals & Control, Inc., Hagan Center, Pittsburgh 30, Pa.*)

FOR THIS LITERATURE CIRCLE 209 ON READER-SERVICE CARD

Automatic Flow Switch



The SHUR-FLO is an electrical inter-locking protective flow switch . . . providing automatic protection to equipment whenever the rate of fluid flow is below or above a safe and critical rating. The SHUR-FLO will operate efficiently on water lines, air lines, or light oil lines . . .

The SHUR-FLO functions by diaphragm from a differential pressure created by the discharge orifice nozzle . . . All that is necessary to change flow rate performance is to change the discharge orifice nozzle . . . (*From 8-page Folder 2600, Automatic Controls Div., Hays Mfg. Co., Erie, Pa.*)

FOR THIS LITERATURE CIRCLE 210 ON READER-SERVICE CARD

NEW PISTON PRESSURE SWITCH

CONTROLS 2 INDEPENDENT ELECTRICAL CIRCUITS

Really TWO pressure switches for the price of ONE

7000 P.S.I. PROOF

*With calibrated dials (both settings can be made visually without gauges). Without dials $29.50. Both prices subject to the usual quantity and trade discounts.

WE BUILD IN	WE DON'T USE
RUGGEDNESS CAN TAKE SURGES (High proof pressures) CONTINUOUS OPERATION (Millions of cycles) NO STICKING (in dirty fluid)	LINKAGES & BEARINGS WHICH WEAR QUICKLY (cause settings to drift and switch to fail).
LABOR & MATERIAL SAVINGS NO RETURN DRAIN PIPING (Sealed piston) MOUNTS WHERE CONVENIENT (Operates in any position, not sensitive to vibration)	UNSEALED PISTONS WHICH ADD TO YOUR INSTALLATION COST (return piping). ARE CRITICAL TO DIRT (pistons get stuck).

PRESSURE SWITCH DIVISION

Barksdale valves

Send for FREE catalog 9-PS.

5125 Alcoa Avenue, Los Angeles 58, California

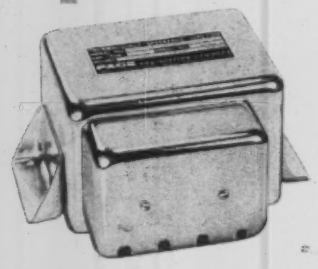
CIRCLE 41 ON READER-SERVICE CARD

PACE

PRECISION IN-FLIGHT REFERENCE JUNCTION

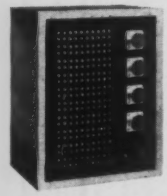
WITH ±1/5°F STABILITY

Solid state, bridge stabilized control provides a precise temperature reference for multichannel thermocouple systems with minimum space, weight and power consumption.



Series FRJ In-Flight Reference Junctions

PACE Series FRJ miniature, In-Flight Thermocouple Reference Junctions are designed for operation on 115 volts, 400 cps. They meet or exceed MIL-E-5272 for Acceleration, Vibration, Altitude and Humidity. Available with up to 24 channels and any reference temperature from 25°F above ambient to 250°F, the new instruments weigh only 2 lbs.



Series BRJ Reference Junctions

For extreme precision in laboratory and ground test applications, PACE builds the BRJ Series Thermocouple Reference Junctions, operating from the 115 volt, 60 cycle line. Temperature Stability and Uniformity for long term unattended operation are within ±1/10°F.

Write today for detailed Reference Junction information. PACE also builds AC and DC Pressure Transducers, Telemetering Equipment and Instrumentation Systems.

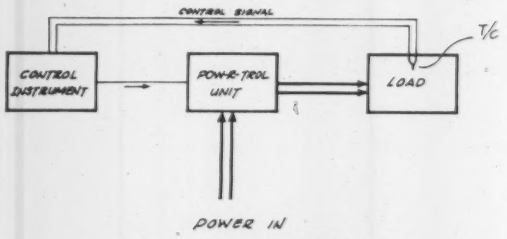
PACE *engineering company*

13035 Saticoy Street North Hollywood, California

CIRCLE 42 ON READER-SERVICE CARD

Control of Power Output by a Power Follower

Multi-zone diffusion furnaces, alloying furnaces, etc. require a large number of control zones for complex temperature profiles. A constant-phase control unit (using silicon control rectifiers) provides high power factor and microsecond response for such complex temperature control.



pHayes-master Control System.

Silicon control rectifiers are less bulky and costly than vacuum tubes, magamps, saturable core reactors, etc. Space savings up to 75% can be realized. Silicon rectifiers can be triggered manually, or by a millivolt control signal from a temperature, pH, or other control instrument. Standard capacities are 10, 15 and 70 amps for 115 or 230 volts, single phase or three phase . . . (*From news release by C. I. Hayes, Inc., 944 Wellington Ave., Cranston* 10, *R. I.*)

FOR THIS LITERATURE CIRCLE 211 ON READER-SERVICE CARD

Frozen Mercury Patterns

To initiate "mercasting," it is necessary to make a steel master mold . . . The liquid mercury is poured at room temperature into the closed mold halves; then the mold and the mercury contained therein is lowered to approximately —125°F, which freezes the mercury rapidly . . . The mercury pattern is then subjected to a series of dips in suspension of two

LOW TEMPERATURE REFRIGERANTS

Refrigerant	Boiling Point at 14.7 P.S.I.A.	Refrigerant	Boiling Point at 14.7 P.S.I.A.
Freon, 12, CCl_2F_2	− 21.6°F	Ethylene, CH_2CH_2	−155.0°F
Freon, 22, $CHClF_2$	− 41.4°F	Freon, 14, CF_4	−198.2°F
Propane, $CH_3CH_2CH_3$	− 43.7°F	Methane, CH_4	−258.5°F
Kulene, 131, $CBrF_3$	− 73.6°F	Oxygen, O_2	−297.4°F
Freon, 23, CHF_3	−115.7°F	Nitrogen, N_2	−320.6°F
Freon, 13, $CClF_3$	−114.6°F	Hydrogen, H_2	−422.9°F
Ethane, CH_3CH_3	−127.5°F	Helium, He	−450.4°

Dry Ice CO_2 Evaporation Point − 109°F

sizes of refractory materials, resulting in a refractory layer approximately ⅛" thick . . . After curing by firing, the "green" investment mold, having released the mercury, is ready for metal casting process.

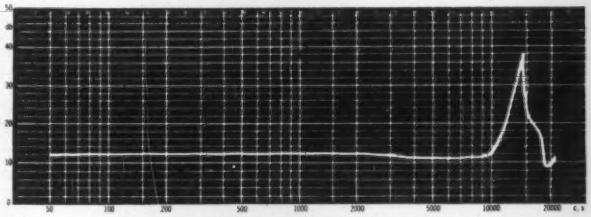
Castings made in this manner can be held to tolerances of about ±0.003 inch per inch of critical dimensions. The resulting smooth finish may, in many cases, render finish machining unnecessary . . . Castings produced by this process may range to 300 pounds. Thin sections, intricate shapes and sharp edges may be successfully secured because of the accuracy with which a frozen mercury pattern reproduces and maintains the shape of the master mold . . . (*From* 32-*page Bulletin* 600, *"Controlled Atmospheric Conditions," Weber Mfg. Co., Inc., Box* 217, *Indianapolis, Ind.*)

FOR THIS LITERATURE CIRCLE 212 ON READER-SERVICE CARD

BRIEFS

Vibration Exciter

Questions and answers are intended to acquaint you with just a few of the many ways the versatile VS-10 outperforms any other unit of comparable size . . .



Frequency Response Curve, 2-oz. Load.

Q. What is the mass of the moving system, and what is the stiffness of the suspension?

A. Nominally ¼ lb., usually about 3¼ oz. with a stiffness of 25 lbs/in.

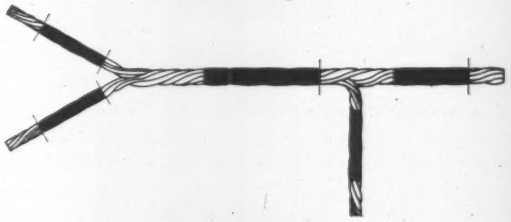
Q. What is the maximum displacement and can this be increased on special order?

A. Nominally 3/16", usually ¼" is possible. The displacement away from the pole piece can be increased if necessary, or custom models with considerably increased displacement but slightly lowered resonant frequency, can be supplied . . .

Accelerometer Calibration: The VS-10 is particularly suitable for this purpose. Full thrust is available to 27 kc/s. Up to and beyond this frequency, a standard and unknown accelerometer can be mounted to have identical motion. The mounting thread is continuous to the inside of the armature, where there is ample room to mount a small accelerometer . . . (*From 12-page brochure, Vibrasonics, Inc., 10 High St., Boston 10, Mass.*)

FOR THIS LITERATURE CIRCLE 213 ON READER-SERVICE CARD

Harness Fabrication Techniques



Thermofit after heating

Thermofit flexible, electrical insulating, extruded tubing can be installed easily because the diameter of tubing, as supplied, will be considerably larger than the diameter of the wire harness bundle to be covered. When Thermofit is heated, it will shrink and grasp the wire bundle tightly . . . It is tough, abrasion resistant . . . has excellent resistance to chemical acids, alkalies, and hydrocarbon solvents . . . (*From 12-page Bulletin RT-2000, Raychem Corp., Oakside at Northside, Redwood City, Calif.*)

FOR THIS LITERATURE CIRCLE 214 ON READER-SERVICE CARD

So SIMPLE
We Can
Adapt It
to ANY
LIQUID LEVEL
CONTROL JOB
A sleeve, raised and lowered within a non-magnetic tube, attracts or releases an Alnico magnet attached to a mercury switch. Basically, this is Magnetrol.
MAGNETROL

AS DEPENDABLE AS MAGNETIC FORCE ITSELF

● No matter how specialized the liquid level control application, adapting Magnetrol to meet it presents no problem. Whether it's for high pressures, high temperatures, corrosive liquids or any other condition, a few "standard" modifications and the job is done! Operation is so simple no changes in basic design are needed. That's why Magnetrol "fits" practically any application — why "specials" are so often standard with us.

Because of the utter simplicity and dependability of its magnetic principle, Magnetrol has *infinite operating life.* There are no wearing parts to get out of order.

Magnetrols are available for controlling level changes from .0025-in. to 150-ft., with single or multi-stage switching. Our experienced engineering staff is at your service.

MAGNETROL, Inc.

WHY NOT MAIL THE COUPON — NOW

MAGNETROL, Inc., 5326 Belmont Road, Downers Grove, Ill.
Please send me catalog data and full information on Magnetrol Liquid Level Controls.
Name _____
Company _____
Address _____
City _____ Zone _____ State _____

CIRCLE 43 ON READER-SERVICE CARD

IDEAL

Thermo-Tip®

RESISTANCE SOLDERING TOOLS

NEW easier-to-handle "Pistol-Grip" Style

Speed Assembly Line Work

up to

42%*

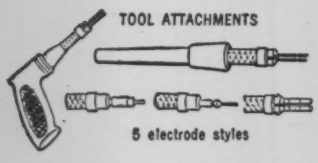
greater reliability for soldering pin-type plugs, aircraft connectors, wire-to-wire, terminals, instruments, printed circuits, electronic systems and parts.

- higher soldering speed reduces costs
- higher-quality connections — fewer rejects
- better, more accurate work on miniaturized assemblies
- light, easy-to-handle — women can use all day without fatigue
- entirely safe, heat only on contact — no operator burns

*Proved by on-the-job comparisons . . . ask for Bulletin C217

COMPLETE LINE OF EQUIPMENT FOR ALL NEEDS

TOOL ATTACHMENTS



5 electrode styles

3 POWER UNIT SIZES

500-Watt 250-Watt 125-Watt

GET THE FACTS... send coupon NOW!

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1420-B Park Ave., Sycamore, Ill.

Send new Thermo-Tip Catalog ☐ Bulletin C217 ☐

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Company_____

We Manufacture_____

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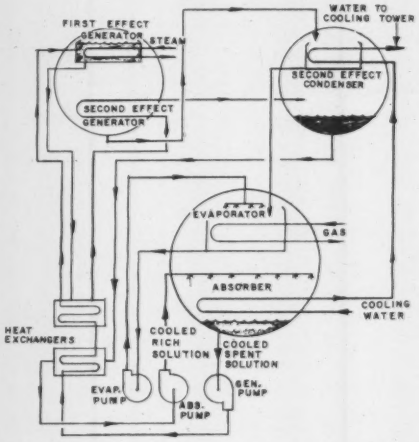
CIRCLE 44 ON READER-SERVICE CARD

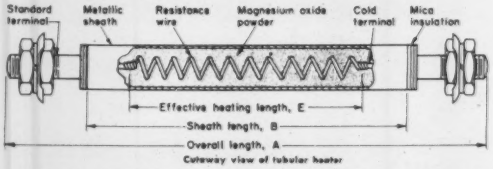
Absorption Cooler Two-Effect Generator

In the application of the two-effect generator principle of operation, heat is applied to a spent solution of lithium bromide in the first effect generator. The solution boils, liberating water vapor, and produces a more concentrated solution. The concentrated lithium bromide then passes through a coil which serves as a second effect generator. The pressure in the second effect generator is lower than that of the first effect generator. Because of this reduced pressure, the solution boils at a lower temperature than that of the condensing vapor from the first effect generator. In this process there is one Btu removed from the chiller for each Btu of heat supplied to the unit, and this now makes cooling as cheap as heating . . . (*From 3-page news release and 8-page Catalog, Statham Instruments, Inc.*, 12401 *W. Olympic Blvd., Los Angeles* 64, *Calif.*)



FOR THIS LITERATURE CIRCLE 215 ON READER-SERVICE CARD

Tubular Heaters



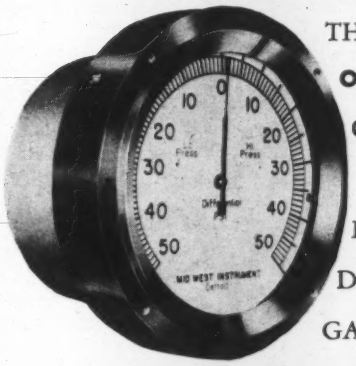
Cutaway view of tubular heater

Any electrical heating problem can be easily solved by determining the heat required to do the job, converting the heat requirement to electrical power required, and selecting the most practical heater of the desired electrical power rating . . . Most heating applications can be divided into two major considerations: A. Heat required for initial heat-up, B. Heat required for normal operation . . . The power needed for either initial heat-up or normal operation will be the total of four heat requirements . . . heat absorbed by the materials, . . . heat absorbed by fusion or vaporization of the materials, . . . heat losses, . . . safety factor . . . (*From 48-page Catalog GEC-1005K, covering heater types, applications, sample calculations, etc.— Industrial Heating Dept., General Electric Co., Shelbyville, Ind.*)

FOR THIS LITERATURE CIRCLE 216 ON READER-SERVICE CARD

DIFFERENTIAL GAUGES

by **MID-WEST**



THE **ORIGINATORS** OF THE SINGLE BOURDON DIFFERENTIAL GAUGE

MID-WEST GAUGES ARE EXTREMELY SENSITIVE, DURABLE, AND ACCURATE. WORKING PRESSURE OF 4,000 PSI IS STANDARD.

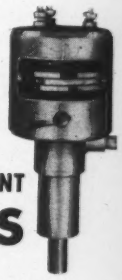
DIFFERENTIAL RANGES FROM 100 INCHES OF WATER. FULL OVERRANGE PROTECTION IN EVERY INSTRUMENT. BI-DIRECTIONAL AND UNI-DIRECTIONAL MODELS ARE STANDARD.

MID-WEST INSTRUMENT DIV.

ASTRA ASSOCIATES, INC. **1021 E. STATE FAIR**
TWinbrook 3-8250 **DETROIT 3, MICHIGAN**

CIRCLE 45 ON READER-SERVICE CARD

SPEED SENSITIVE



1 to 6 ELEMENT SWITCHES

OVERSPEED

One S.P.D.T. switch to trip at speeds between 350 and 6,000 RPM.

OVER AND UNDERSPEEDS

Two S.P.D.T. switches to trip at two different speeds between 300 and 6,000 RPM.

UNDERSPEED

One S.P.D.T. switch to trip at speeds as low as 250 RPM. Maximum operating speed 5,000 RPM.

OVER INTERMEDIATE AND UNDERSPEED

Six S.P.D.T. switches to trip at six different speeds between 300 and 6,000 RPM.

EXPLOSION PROOF AVAILABLE

The switches listed above are available with explosion proof containers that meet all of the specifications of Class 1, Group D, explosion proof equipment.

For further information ask for Bulletin 604

SYNCHRO-START PRODUCTS, INC.
8151 N. RIDGEWAY AVENUE, SKOKIE, ILLINOIS

CIRCLE 46 ON READER-SERVICE CARD

Select from over 3,500 different SOLENOID VALVES from VALCOR

Series SV-54 (3 way-4 way) general purpose solenoid valves for air, oil and water. Rugged construction, yet inexpensive. Multi-million cycle life. Pressure ratings up to 150 psi. Nylon seat outlasts steel. Infinite varieties available . . . lists as low as $10.75.

Series SV-61 (2 way) Nylon body valve is ideal for general purpose and OEM installations where millions of operating cycles are vital. Nylon seat and port threads outlast steel, yet cost less. Non-corrosive, shock-resistant, proof-pressure.

Series SV-5100 Specifically designed to handle the most corrosive media in industry. Manufactured in Teflon, PVC and Nylon varieties. Diaphragm construction prevents media contact with any metal. Available in direct-acting or piloted models.

VALCOR SOLENOID VALVES

FREE . . . new 16 page brochure —lists over 500 corrosive media—coded for correct valve selection.

For complete information on these or other models, write or call:

VALCOR ENGINEERING CORP.
5366 Carnegie Ave., Kenilworth, N. J.
CHestnut 5-1665

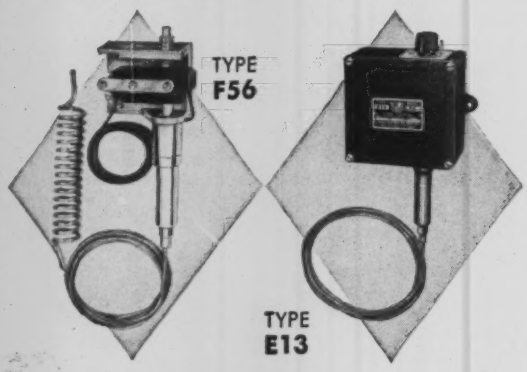
CIRCLE 47 ON READER-SERVICE CARD

Improved Design

REMOTE BULB TEMPERATURE CONTROLS

F56 / E13

WIDE RANGE — CALIBRATED



The F56 and E13 are functionally similar controls. Type F56 is a wide range, uncalibrated, skeleton unit designed for use in ovens, incubators, and other applications where space or weight is a limiting factor. Type E13 is a narrow range, calibrated, enclosed unit intended for similar applications but under conditions where an enclosure and external adjustment knob and dial are desirable. Explosion proof unit, Type E98, is also available.

Temperature Ranges	F56 . . . up to maximum limits of −150° to +150°F, 70° to 370°F, or 100° to 650°F. E13 . . . 100° or 200° spans between −150° and +650° F limits.
Switch Ratings	15 or 20 amps at 115 or 230 volts AC. DC switches also available.
Switch Types	N.O., N.C., or Double Throw, no neutral position.
Adjustments	F56 . . . slotted range adjustment screw on top, uncalibrated settings. E13 . . . external knob and pointer, calibrated settings.
Electrical Connections	F56 . . . 12-inch lead wires attached directly to switch terminals. E13 . . . to internally located terminal block via conduit opening in enclosure.
Capillary Tube Length	6-foot standard length. Other lengths available.
Mounting	E13 . . . surface mounted in any position by means of dog ears. May be flush mounted. F56 . . . Surface mounted in any position by holes drilled in base of bracket. May be flush mounted.

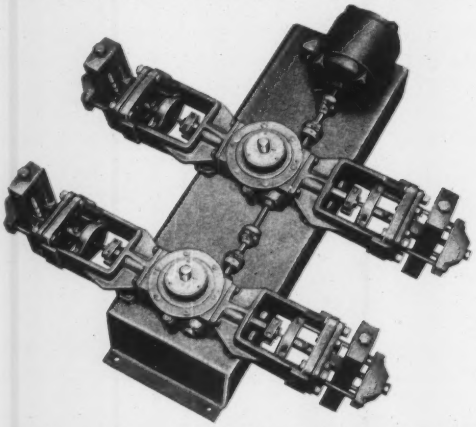
UNITED ELECTRIC *manufactures a complete line of temperature, pressure, and vacuum controls. For additional data on the remote type temperature controls, including types F56 and E13, request* Section 200 *of our* new *catalog.*

United Electric Controls COMPANY
89 SCHOOL STREET, WATERTOWN, MASS

CIRCLE 48 ON READER SERVICE CARD

Metering Pump

The Wallace & Tiernan Series 200 Metering Pump is an electrically driven, positive-displacement, reciprocating, plunger-type pump. Capacities range from 0.65 to 2025 gallons per hour. It gives repeatable metering

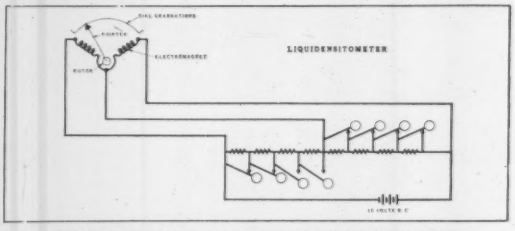


accuracies within ±1%. Standard models operate against pressures up to 4000 psi . . . The Series 200 Pump consists of a standard electric motor, drive unit, crosshead, and 1, 2, or 3 liquid ends—all mounted on a heavy steel base plate . . . The pump drive shaft runs in heavy ball bearings. The load is applied solely between these bearings. The packing take-up and liquid end clamping are self-aligning. Where a single packing take-up bolt is used, it is located where it cannot be corroded by contact with the materials being pumped . . . (*From* 12-*page Catalog* 420.200, *Wallace & Tiernan Inc.*, 25 *Main St., Belleville* 9, *N. J.*)

FOR THIS LITERATURE CRCLE 217 ON READER-SERVICE CARD

Remote Reading Density

Use of a dial type ratiometer indicator in conjunction with a Liquidensitometer results in a remote reading density indicating system . . . The up and



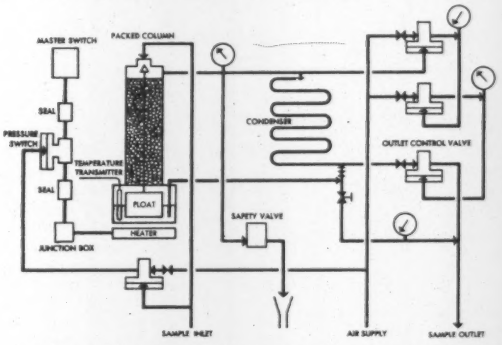
SIMPLIFIED SCHEMATIC DIAGRAM, LIQUID DENSITY INDICATING SYSTEM

down position of the floats is determined by the density of the liquid being measured. This, in turn, determines the apportionment of resistance across the electromagnets in the indicator. The magnetic field set up by the electromagnets positions a permanent magnet rotor suspended in the field on jeweled bearing. The indicator pointer is attached to the rotor and indicates density on a suitably graduated dial . . . Systems for almost any range of densities can be provided by varying the number of floats in the Liquidensitometer and the weight increment between them . . . (*From* 16-*page Bulletin* 522*A, Liquidometer Corp., Long Island City* 1, *N. Y.*)

FOR THIS LITERATURE CIRCLE 218 ON READER-SERVICE CARD

End-Point Analyzer

The TOTCO End-point analyzer, . . . a process analyzer for continuously indicating the ASTM end point of a product as it is manufactured, . . .

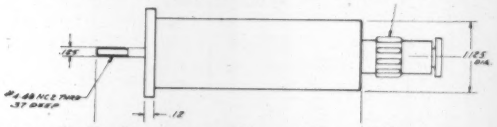


As the end boiling point of the sample starts to rise, there is a decrease in the percentage of the incoming sample that is converted to vapor in the tower. This results in an increase in the amount of sample reaching the reboiler. As the liquid level rises in the reboiler, the float control decreases or shuts off incoming sample. The heat input of the reboiler is constant, so the temperature rises until the equilibrium is reached . . . (*From* 4-*page Bulletin* 5900-11, *Technical Oil Tool Corp.*, 1057 *N. LaBrea Ave., Los Angeles* 38, *Calif.*)

FOR THIS LITERATURE CIRCLE 219 ON READER-SERVICE CARD

Transducers

New Series IP-1120 Potentiometer Linear Motion Transducers are used for remote indication, recording, or control systems which require the precise measure-



ment of displacement, elongation, thickness. . . . Matched output can be provided for all units regardless of stroke thus allowing multi-point operation and direct field interchangeability. The inherent capacity to provide a high-level output signal allows operation with nearly all readout or control instruments without preamplification . . . (*From* 16-*page booklet, H. E. Sostman & Co.*, 347 *E. Lincoln Ave., Box* 60, *Cranford, N. J.*)

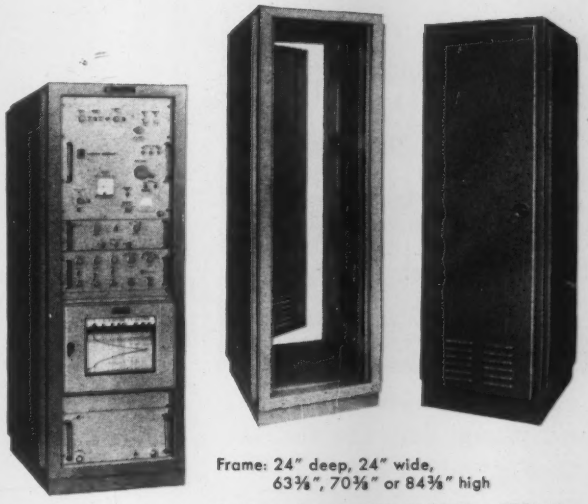
FOR THIS LITERATURE CIRCLE 220 ON READER-SERVICE CARD

Digital Transducers

DeJur Digital Transducers are self-contained solid state miniaturized packages designed to measure various parameters (pressure, temperature, flow, acceleration) and supply a digital signal output without auxiliary equipment The result can be a pulse duration type (PDM) digital signal whose pulse width in time is directly proportional to the amplitude of the input parameter being measured. PPM and PFM outputs also can be made available . . . (*From catalog, Electronics Div., DeJur-AMSCO Corp.*, 45-01 *Northern Blvd., Long Island City, N. Y.*)

FOR THIS LITERATURE CIRCLE 330 ON READER-SERVICE CARD

"PACKAGED" PROTECTION FOR YOUR CONTROLS



Frame: 24" deep, 24" wide,
63⅜", 70⅜" or 84⅜" high

Front panel space: 56", 63", 70" or 77" high

New Honeywell Modu-Mount* Cabinets

Now you can get standard enclosures to protect your valuable precision instruments and devices. New Honeywell Modu-Mount Cabinets are designed by experts to provide the ultimate in appearance, convenience and economy. Best of all, you can order them to fit your specific enclosure requirements.

The rugged steel frame can be left open or enclosed by panels and doors. You can specify such features as anti-tilt mobile base, wiring trough, lift-bars and eyebolts, or floor levellers, vibration mounting and cooling louvers. And up to five Modu-Mount Cabinets can be supplied with a common base and wiring trough.

Modu-Mount Cabinets come in standard green, grey or brown baked enamel. Other colors are available at your request. For details, call your nearby Honeywell office. Or write Honeywell, Dept. IC-2-55, Minneapolis 8, Minnesota. *Sales and service offices in all principal cities of the world.*

HONEYWELL CUSTOM ENCLOSURES

Honeywell will design and custom-build any cubicle, panel, console or other enclosure to your exact specifications. Special attention is given to these orders, and the finished product meets the most stringent requirements.

Honeywell

First in Control

SINCE 1885

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CIRCLE 49 ON READER-SERVICE CARD

US KELLOGG GRAVER

Judging by the Company We Keep...

Electro-Mech

. . . "The Company We Keep" will accept only the best in control center design.

The console shown above, part of a large control system for a modern process plant, is an example of Electro-Mech functional design excellence which *means* the best.

Allow us to quote on your entire control system requirements.

Electro-Mech Corp. Norwood, N. J.

Electro-Mech

· CIRCLE 50 ON READER-SERVICE CARD

ICS PANHANDLE PETE

WESCO! Symbolic-Logic Computer

It is well known that the greatest future for electronic computers lies in the field of self-adjusting optimal decision making via logical programming of premises. This is the great new field of *symbolic logic*, using symbols AvBvC, etc., (which all readers of *I&CS* now know.—Ed.) The WESCO! digital computer is the first digital computer with logic elements that will take any given number of premises and arrive at the logical conclusion via symbolic logic.

The first machine has been delivered to the U. S. Government (where else?) and we are proud that it is being used in many different departments. Books, dictionaries, and newspapers are fed into the computer where they establish the programmed premises; the conclusions are typed out along with the premises that were used to arrive at the conclusion, plus the symbolic logic used.

Naturally, the world is waiting for the detailed report of how the computer is operating, so we sent our genial sales manager, Waldo Klappsaddle, down to Washington to get a first-hand report—here he comes now.

"Waldo, is the machine being used in the State Department where it was sent?"

"No," replies Waldo.

"Didn't it work?" I asks.

"They only tried one problem," sadly replies W. "Here it is." He hands me a sheet typed out by our fine automatic-typewriter (speed 749-420 words per second) as follows:

Problem 1: $(A \cdot B \cdot C) \vee \overline{A} \cdot B \vee \overline{C} \cdot A$

A. Nations often go to war
B. They usually use the most powerful weapons on hand.
C. Nuclear weapons can destroy civilization.

Computer Conclusion: QUICK WAY TO DESTROY CIVILIZATION IS TO ARM MANY NATIONS WITH NUCLEAR WEAPONS.

"Seems the State Department took one look at the conclusion and shipped the machine over to the Treasury Department," says Waldo.

"What happened there?" I asks.

"Well, this is the problem they put on the machine," says Waldo, as he hands me a treasury document marked TOP SECRET:

Problem 2: $(\overline{A} \vee B \cdot C) \vee A \cdot \overline{B} \vee C \cdot \overline{B} \vee \overline{D}$

A. USA federal government Research and Development expenditures for Department of Defense for military purposes in 1960 were $5.6 billion.
B. USA federal government Research and Development expenditures for Department of Health, Education and Welfare in 1960 were $0.24 billion.
C. Definition of barbarian: One who lacks humanitarian feeling for and is insensitive to human suffering.
D. Definition of humanitarian: Having feelings proper to man; cultured; acting rightly to others.

Computer Conclusion. USA IS 23.3 TIMES MORE BARBARIAN THAN HUMANITARIAN

"Seems like the Treasury Department took one look at the conclusion and sent the machine over to the AEC," says Waldo.

"What happened there?" I asks, beginning to get a little worried.

"Well, here is their problem," says Waldo, as he hands me the following:

Problem 3: $(A \vee \overline{C} \cdot B) \vee (A \cdot \overline{C}) \cdot (\overline{B} \vee C)$

A. Clean atomic weapons have no radioactive fallout.
B. Test inspection systems measure radioactive fallout.
C. Test inspection systems are the first step in control of nuclear weapons.

Computer Conclusion: WHEN CLEAN BOMBS ARE DISCOVERED THERE WILL BE NO HOPE FOR CONTROL OF NUCLEAR WEAPONS

"The AEC took one look at the conclusion and shipped the computer over to the Department of Health, Education & Welfare, and this is the result":

Problem 4:
$(A \vee B) \cdot (\overline{B} \cdot C \vee A) \cdot (\overline{A} \vee C) \cdot (D \vee \overline{C}) \cdot E \vee F$

A. Educated technical manpower is a national asset for years.
B. Quality teachers are essential to obtain educated technical manpower.
C. Low pay for teachers causes good teachers to leave profession.
D. Military equipment becomes obsolete quickly.
E. Average pay for teachers in USA is $6200.
F. Average pay for missile engineers in USA is $12500.

Computer Conclusion: USA TEACHER MIGRATION TO MISSILE JOBS WILL RESULT IN DECLINE IN TECHNICAL MANPOWER WHILE USA WASTES SUBSTANCE ON RAPIDLY OBSOLESCENT MILITARY EQUIPMENT. NATION THAT SPENDS MOST ON EDUCATION WILL END UP MOST POWERFUL AND PROSPEROUS.

"Without giving the computer another chance, off it went to the Dept. of Commerce and here's the result," says Waldo, no longer genial:

Problem 5:

A. Average leading USA missile manufacturer earns $150,000 per year.
B. Average leading USA entertainer earns $100,000 per year.
C. Average leading USA teacher earns $6200 per year.
D. Average USA nurse earns $4000 per year.
E. Social usefulness is a function of contribution to health, education and welfare of society.
F. Salaries are amounts earned by human human beings for their labor.

$$(A \cdot B \cdot \bar{C}) \vee (E) \cdot (\bar{B} \vee \bar{E}) \vee \bar{A} \cdot F$$

Computer Conclusion: SALARIES IN USA ARE INVERSELY RELATED TO SOCIAL USEFULNESS OF THE LABOR.

"You can guess what happened," says Waldo, "over it went to the Agriculture Department, where the first (and last) problem was:"

Problem 6:

A. Forty billion barrels of foods are rotting in USA storage bins.
B. People are hungry all over the world.
C. Billions of dollars are being given to USA farmers not to grow more food.
D. USA Government is spending billions buying food to keep prices high.
E. Storage costs are millions of dollars per day.
F. Inflation causes misery to hungry unemployed and low fixed-income groups.
G. There are more than 4 million USA unemployed.
H. It is immoral and heartless to deny food to the hungry.
I. It is stupid and ridiculous to cause inflation.
J. It is insane to purchase food only to have it rot in storage.

Here the machine started typing over and over at maximum speed—

$$A \vee \bar{C} \vee D \vee (\bar{A} \vee B) \vee \bar{C} \cdot D \vee (\bar{E} \vee A) \vee (\bar{G} \vee C) \vee (\bar{B} \vee A) \vee I \cdot \bar{J} \cdot H$$

Conclusion. USA AGRICULTURE POLICY IS HEARTLESS, RIDICULOUS, SELF-DEFEATING, INSANE, IMMORAL, STUPID, RIDICULOUS . . . . . .

"Now they are shipping the whole works back to us. Here it comes now with a big reject sign on it."

"What's the sign say?" says I.

Waldo picks up the tag and reads, "'The logic in this symbolic-logic computing machine is too symbolic—please put it to work on military problems like other computers,' signed *The Defense Department*, the *Atomic Energy Commission*, the *Commerce Department*, the *Department of Health, Education & Welfare*, the *Agriculture Department* and *President of the United States of America*."

Panhandle Pete

ARCCO CANNON NEVER-DRY PEN
Writes for Months
REPLACES OTHER MAKES • USES REGULAR INKS
Regardless of pulsations or other causes of ink failures this new Never-Dry Pen will make clean and complete records. Ink supply lasts for several months without refilling reservoir. Capillary tube from ink bottle placed in instrument case feeds pen with continuous flow. Closed system sealed from atmosphere prevents clogging and dirt accumulation.
Weight of pen is constant at all times thus insuring extreme accuracy. No slopping or dripping. Stainless steel construction—no corrosion. When ordering, specify make and type of recording instrument.
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• A Precise voltage regulator . . . max. ±.04% for ±20% voltage variation
• Quickly Installed... Fits present instrument battery space.
• No Tubes to replace
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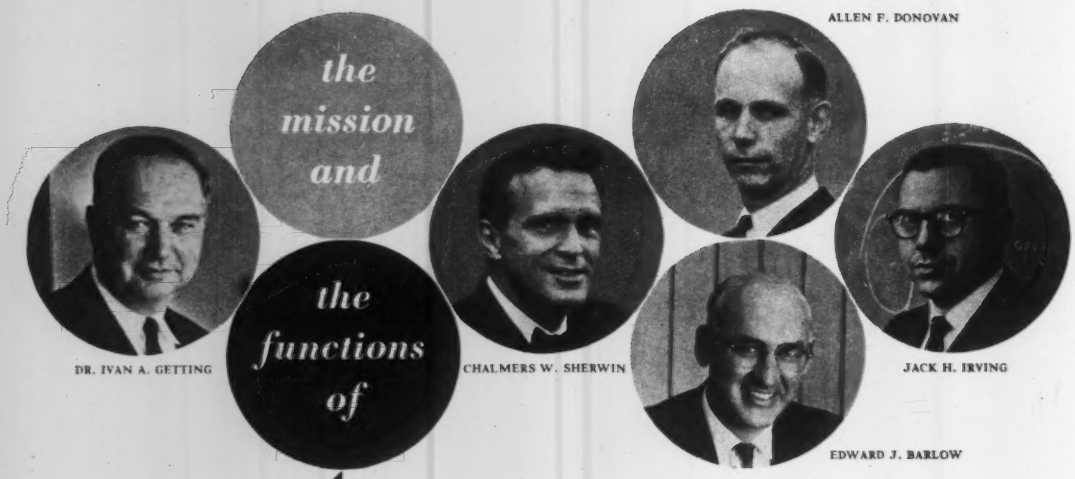

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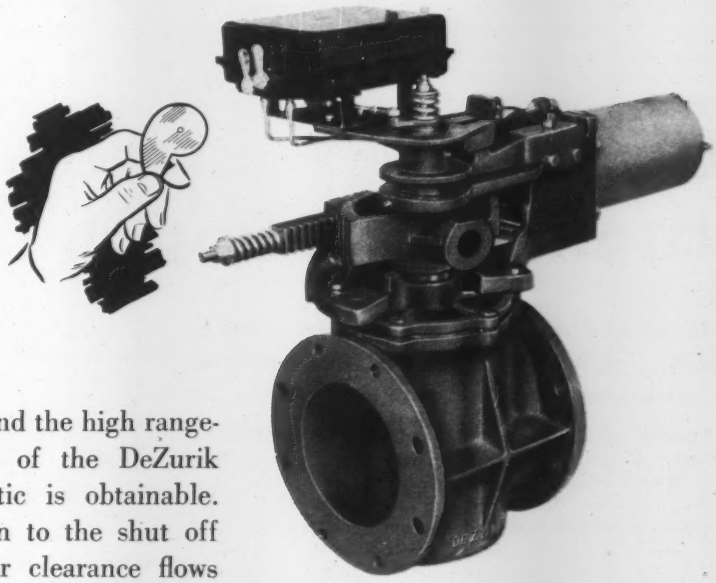

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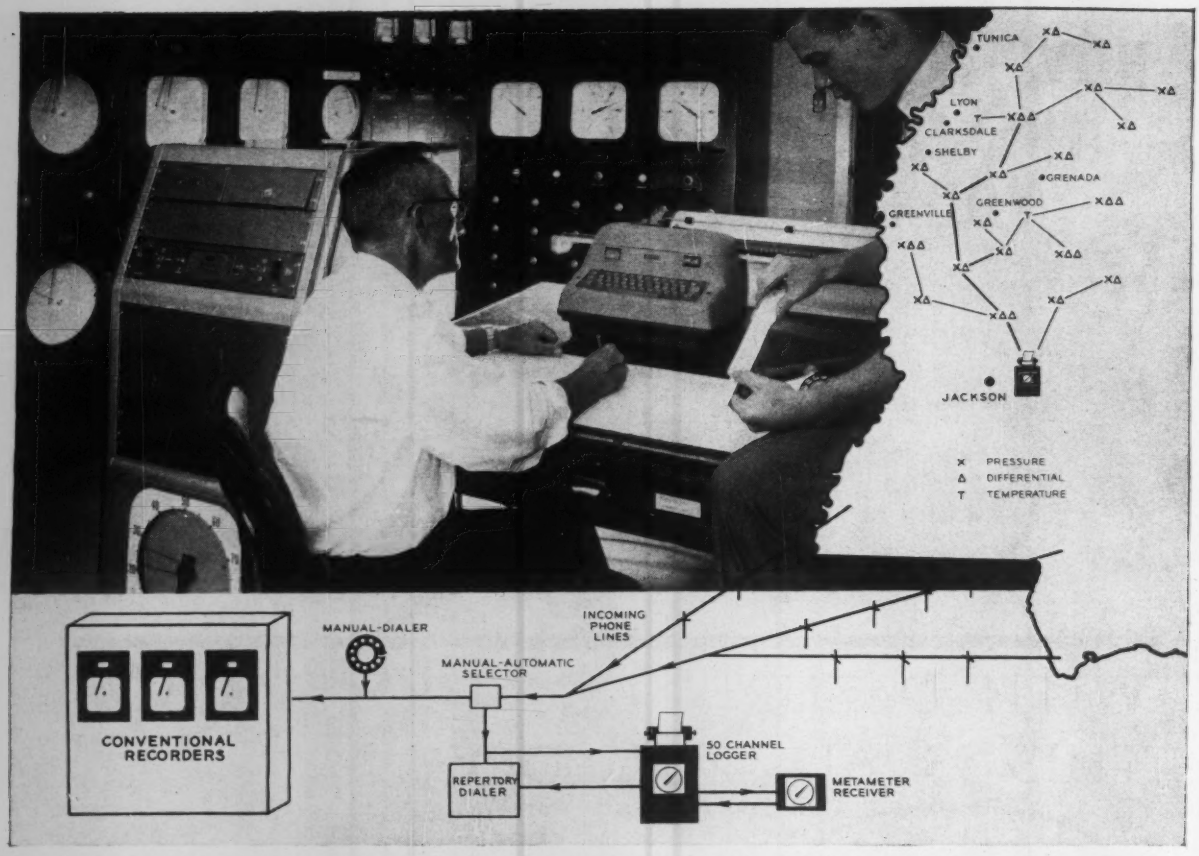

Bristol Metameter* Telemeters (on panels) and Data-Master* digital data logger (foreground) in central dispatcher's office of Mississippi Valley Gas Co., Jackson, Miss. The Data-Master automatically types out instrument readings from points shown on map. (Punched-tape output also available.) **T.M. Reg. U. S. Pat. Off.*

Big change at Mississippi Valley Gas:

Digital Data Logging by Bristol

Amazing boost in telemetering efficiency, economy, and system control effected by "Data-Master" digital data logging.

The Bristol Metameter* Telemetering system at Mississippi Valley Gas Company was already one of the most extensive systems of its kind. At the spin of a telephone dial, the dispatcher, at Jackson, Mississippi, could receive pressure, flow, or temperature readings—49 functions in all—from 21 stations, up to 200 miles away.

Today there's an even greater advance in this outstanding system: "Data-Master" digital data logging equipment, manufactured by Data-Master Corporation, a Bristol subsidiary, has taken over the routine dialing and recording of data. As often as three times an hour, the Data-Master equipment *automatically* "dials" the remote stations (see map), and *automatically* types out the instrument readings on an electric typewriter. All without an instant's attention by the dispatcher. What's more, any time the dispatcher wants a specific reading, he can still manually dial any station for the reading.

Easy avoidance of contract penalties on purchased natural gas, efficient operation at near capacity, ability to give long notice to users classified as "interruptible" (allowing them to switch to standby fuels), freedom of skilled operators from the tedious routine of manually recording instrument readings (and avoidance of errors) are just a few of the benefits reported by Mississippi Valley Gas.

Bristol offers a complete telemetering systems engineering service to natural gas pipelines and distribution systems, oil pipelines, electric power systems, water plants, and industrial plants. Our engineers will welcome an opportunity to discuss your specific telemetering problems, or we'll send you literature. Write: The Bristol Company, 113 Bristol Road, Waterbury 20, Connecticut, a Subsidiary of American Chain & Cable Company, Inc. 0.38

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AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

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1960 Computer Progress

Report by Ad Hoc Group of the AIEE Computing Devices Committee, Presented at AIEE Winter General Meeting, New York City, 30 January 1961.

Committee Members:

G. L. HOLLANDER, Hughes Aircraft Co., Fullerton, Calif. (editor)

EVELYN BEREZIN, Digitronics Corp., New York City, N. Y.

R. S. GILLETT, General Electric Co., Phoenix, Arizona

L. A. GOULD, Massachusetts Institute of Technology, Cambridge, Mass.

R. R. JOHNSON, General Electric Co., Phoenix, Arizona

J. McLEOD, Convair Astronautics, La Jolla, Calif.

D. REAM, Bureau of Ships, Washington, D. C.

D. L. STEVENS, Burroughs Corp., Pasadena, Calif.

New Computers

1960 was the first year that solid-state computers were installed on a commercial basis in the United States, and the switch was so sudden that no significant new machines were delivered that did not use solid-state circuitry.

The first of the large-scale general-purpose solid-state computers to replace the IBM-704s and 709s and the Remington Rand 1103s include the IBM-7090 with its 2.3-microsecond memory, the Philco 2000, and the CDC-1604. Likewise, the first of the solid-state data processors were put into service, including the RCA-501, IBM-7070, and Remington Rand Solid State 80. Remington Rand delivered its LARC, the first computer with the capability of several IBM-7090s or Philco 2000s. Initial deliveries in 1961 were announced for the Honeywell 800, the Bendix G-20, the GE-225, the RCA-601, the IBM-7080, and the IBM-7030 (Stretch).

New small computer systems include the IBM-1401, CDC-160, Monrobot X1, and Packard Bell 250, with several other systems scheduled for introduction in 1961. The IBM-1401 and CDC-160 can operate in conjunction with larger systems, performing special operations as satellites for the IBM-7090, IBM-1410, and CDC-1604 respectively.

Two large-scale digital computers were built especially for a military environment, the Sylvania Mobidic (Sylvania 9400) and the Remington Rand AN/USQ-20 (Remington Rand 1206). Both emphasize the multiple-channel input/output capability needed for many military real-time systems, as do several other special-purpose military computers. The Federal Aviation Agency received its initial computer for air-traffic control from Librascope.

Application to Design, Evaluation and Simulation

Advances in the application of computers to problems of design, evaluation, and simulation have to some extent been the result of improvement in equipment performance, and more versatile and powerful techniques of applying available equipment.

An interesting example of the use of combined simulation to design a control system was the work done by the Control Systems Division of Daystrom, Inc., for the Little Gypsy Power Station of the Louisiana Power & Light Company. The design of that control system required a complete analysis of the system dynamics. An open-loop response test on the equipment at another station which was already in operation provided dynamics data on power operators, primary elements, transducers, boiler-turbine-generator characteristics, etc. Using repetitive analog computer techniques, the transfer function between each input variable and each output variable was established. Analog computer circuits then were designed to represent each transfer function, and the total effect of all inputs on each output were summed up.

This computer simulation, revised somewhat to account for differences in boiler design between the test station and Little Gypsy, was used to check out both the digital computer and analog controls for the combined analog-digital control system for Little Gypsy. This same combined simulation also was used to develop adaptive and non-interacting controls for that plant.

Trends in Organization of Computer Systems

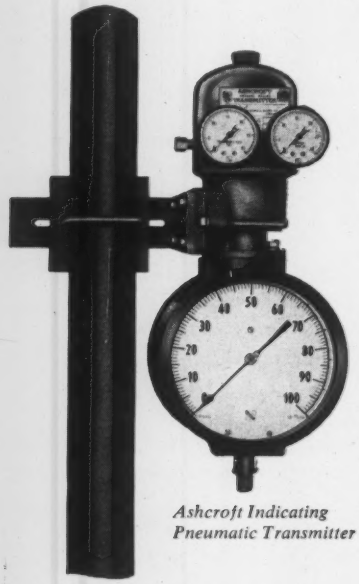
This year has been the year of multiplexing. Almost all of the systems delivered this year include some form of program and input/output time-sharing. There has also been increasing work on the programming services which such machines require—Compilers and Schedulers.

A further effect of the use of high-speed communications networks and more reliable equipment is the greater use of on-line systems, as opposed to batch processing. This has been aided by technical advances in mass storage media (e.g. large drum and disc memories). Projected country-wide and world-wide systems illustrate the overall pattern for 1960—the rapidly growing comprehensiveness with which problems have been attacked in both scope and geography. Daystrom has

Continued on page 231.

signal action

ASHCROFT PNEUMATIC TRANSMITTERS give you a true primary and transmitted signal for indication or control



Ashcroft Indicating Pneumatic Transmitter

Now—detect with precision accuracy the slightest change in primary pressure or temperature. Transmit this signal quickly to your indicators or controllers. Ashcroft Pneumatic Transmitters achieve these results for you at the lowest initial and operating costs.

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Narrow-span Ashcroft Transmitters are expressly designed with highest sensitivity and repeatability for the most accurate primary signal feed to controllers. You get better control and purer, lower-cost final products.

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Write for factful Bulletins 360 and 361 or ask your nearby Ashcroft Distributor to help you select the right transmitters and receiver gauges for your specific requirements.

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even announced a new maintenance service that monitors any of their computers in trouble on a remote console at the factory and transmits correcting instructions by Dataphone link.

Computer Control

Whereas less than half a dozen installations went on-line in 1959, the current year should see possibly twice this number of control computers in operation, with many more in the planning or installation phase.

The electric utility industry probably has been the most active, with a number of digital computers being installed for data collection, process monitoring, calculation of operating guides, economic dispatch of generation and interchange billing, and perhaps most significantly automatic start-up and shut-down of boiler-turbine-generator units. Pioneers in this industry are Southern California Edison, Louisiana Power & Light, Philadelphia Electric Company, Public Service of New Jersey, South Carolina Electric & Gas. Possibly the most significant event was the announcement that the digital computer at the Sterlington Station of Louisiana Power & Light (Daystrom Systems) successfully passed a 6-month acceptance test with better than 99-percent availability. This figure may become a standard performance specification for future control computers.

In the petro-chemical area, results of some early installations were released during the year. B. F. Goodrich reported favorably on a computer which controlled the operation of two plants, one making vinyl chloride and the other acrylic plastic. Monsanto published its experience with a computer-controlled ammonia plant.

Heavy industry, particularly steel, has also embarked on a number of automation projects. Jones & Laughlin has placed a computer-controlled continuous annealing line in operation; Great Lakes' automated hot strip mill should be in operation by the end of the year. Other projects are in progress to automate blast furnaces and open-hearth furnaces. The cement industry is looking forward to the first digital computer which will control not only the operation of the kiln but also the mixing and blending operations.

Significant is the number of new entries in the list of suppliers of computer control equipment. In addition to Thompson-Ramo-Wooldridge, Daystrom Systems, General Electric, Minneapolis-Honeywell, Philco with Leeds & Northrup, Foxboro with RCA, Autonetics, and Librascope-GPE, we find a number of newcomers. These include Packard-Bell working with Bailey Meter Company, Control Data which acquired Control Corporation, Information Systems which is a merger of Panellit with Genesys, Westinghouse, Allis-Chalmers which acquired Consolidated Engineering Corporation, and Cutler-Hammer which acquired Airborne Instruments Laboratory to supply electronic control equipment. Remington-Rand has entered the field with its UNIVAC 490.

Medical

The medical profession is starting to use computers. An example is the Rand Corporation's simulation for the Air Force of the physical chemistry of the human respiratory and circulatory systems. This dynamic simulation considers the partial pressures of the constituents of the inhaled and exhaled air, the mixing in the lungs, the transport in both directions through the membranes of the alveoli, the chemical composition of the blood serum, the transport in both directions through the membrane of the blood cells, and the chemical composition of the blood cells—some 53 interdependent variables.

The use of computers to simulate biological as well as the physical and chemical processes of the body also shows great promise both for analysis and synthesis. Enough work has already been done using computers to analyze, correlate and evaluate clinical and laboratory data to predict that computers will become an extremely powerful aid to diagnosis. Systems Development Corporation has a project from the Veterans Administration to generate programs for keeping medical data files on all patients, and for new mathematical models for utilizing soft (incomplete or inconsistent) data.

This survey would not be complete without mention of the advances made in the application of what might be generally classed as Intelligent Machines; computers which can to some degree learn from experience, recognize patterns, organize themselves, adapt their responses to changing conditions, or in some other ways display what can be considered some degree of intelligence. Aeronutronic, General Electric, Bell Laboratories, and Westinghouse have worked on solid-state elements simulating neuron action for self-organizing or adaptive systems. Attempts to use computers to simulate thought processes have not only yielded some information about how the brain might work, but also how computers might work better.

New Techniques and Devices

General Electric announced a thermoplastic recording which may eventually allow storage densities of 40 million bits per square inch while maintaining the processing speed and versatility of magnetic recording.

Tunnel diodes and thin films have become standard components for the circuit designers with the drive toward higher speeds and smaller size. Commercial computers with 2-microsecond memories were delivered, and memories with cycle times on the order of 0.1 microsecond are under development. Furthermore, thin films are being used as logic components.

In the laboratories, efforts are being directed toward the next break-through—the gigacycle computer. Spurred by Project Lightning, breadboards of arithmetic elements and memories are under test that operate 300 to 1,000 times faster than their present counterparts.

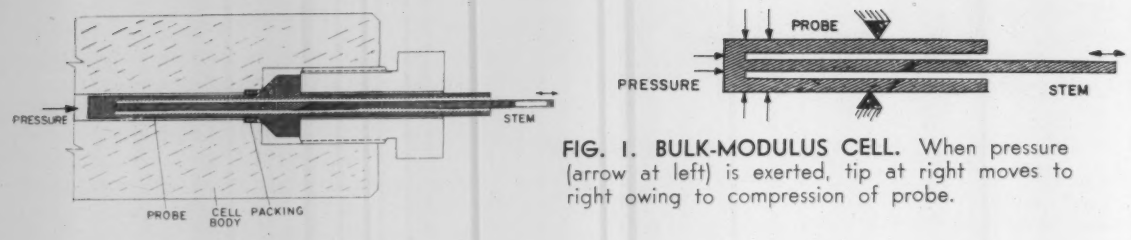


FIG. 1. BULK-MODULUS CELL. When pressure (arrow at left) is exerted, tip at right moves to right owing to compression of probe.

High-Pressure Measurement

The new bulk-modulus-cell high-pressure gage provides ruggedness and reliability for the ranges between 0-50,000 and 0-200,000 psi.

DONALD H. NEWHALL
LEONARD H. ABBOT
Harwood Engineering Company, Inc.

HIGH-PRESSURE-MEASUREMENT technique depends on many factors. For instance, if precision is the prime consideration the free-piston gage comes to mind. But the free-piston gage is slow and thus limited to its principal purpose, a primary standard.

All other high-pressure-measuring devices are secondary and depend on a free-piston gage for calibration. Most use the principle of elastic deformation. Among these are the bourdon gages (including the long helical form recently developed by the Foxboro Company), the strain gage, and new bulk-modulus cell.*

None of these devices follows Hooke's law precisely. In any instrument of this class hysteresis of at least 0.1% of full scale is inevitable.

At high pressures the bourdon tube walls must be thick, which makes the tube stiff, and hence the length of scale is reduced.

The long helical form of the bourdon gage spreads the required deflection over several turns of the tube, which makes it possible to build gages of much greater range without sacrifice of strength; the long helical form can be rated up to 80,000 psi. Moreover, it can be used at full scale and even overloaded considerably without affecting the calibration. In marked contrast, it is standard practice in industry to operate common bourdon indicators at no more than three-quarters (preferably one-half) of full scale. Indeed, most of the bourdon tubes designed for more than 20,000 psi are rather weak for their rating.** A notable exception to this generalization could be a bourdon element with electrical amplification, requiring a much smaller deflection for full-scale indication.

Another important pressure gage is the manganin-type cell. (Other materials, such as gold-chromium or lead, also have been used.) A small coil of manganin wire is subject to the high pressure. The change in resistance of the coil is measured by a bridge. Manganin alloy has a large, positive, linear pressure-resistance relationship and, under ordinary conditions, is relatively insensitive to temperature fluctuations. Manganin cells can yield accurate measurements to over 400,000 psi. They have been used for ten years, but are delicate.

The Bulk-Modulus Cell

The bulk-modulus cell (Fig. 1) comprises a hollow cylindrical steel probe, closed at its inner end. It is introduced into a thick-walled steel cylinder, the cell body, which is exposed to the high-pressure system. The probe is held in place by a threaded retainer which also serves to compress a conventional packing between shoulders on the cell body and probe. A stem projects one inch beyond the outer end of the probe proper. A clearance of 1/64″ between the stem and the wall of the probe assures free stem motion.

When the active part of the probe (from the packing inward) is subjected to pressure it contracts isotropically. Its compression results in a displacement outward of the tip, because the shoulder is held fixed against the housing. Tip displacement moves the stem outward, increasing the distance it projects beyond the outer end.

The present probe is suitable for ranges from 0-50,000 to 0-200,000 psi. Higher pressures are

*Patent applied for.

**The authors contend that safety factors should be included in the specifications for all pressure-measuring devices.

TABLE 1—RANGE AND ACCURACIES OF COMPARABLE GAGES

Instrument Type	Available Ranges (psi) Minimum	Maximum	Accuracy (% full scale)
Bourdon	———	0-100,000	0.2 to 5*
Strain Gage	———	0- 50,000	0.25
Long Helical	———	0- 80,000	0.5
Bulk Modulus	0-50,000	0-200,000	1.0
Manganin	0-50,000	0-425,000	0.1 to 0.5**

*Depending on range and manufacturer.

**Depending on instrumentation.

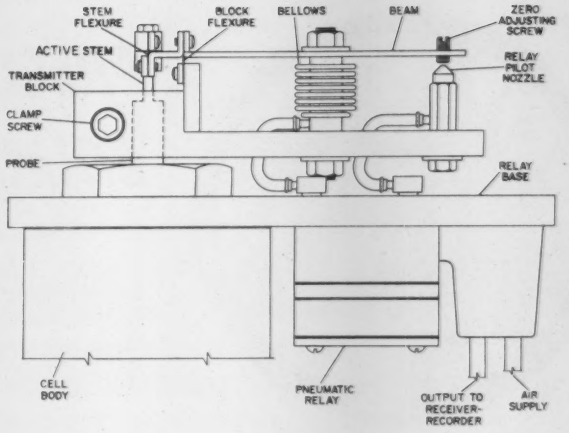


FIG. 2. FOXBORO pneumatic transmitter detects tip motion of probe. Supply is 20 psig. Tip motion produces proportional 3-15-psig signal.

contemplated, though no industrial processes except diamond synthesis are known to operate above 200,000 psi.

Stem motion can be measured by (1) an electromagnetic pickup, (2) a capacitance pickup, or (3) mechanical displacement pickup. A mechanical displacement unit operating a pneumatic transmitter has been developed by the Foxboro Company (Fig. 2). This appears to have important advantages and is used with a Foxboro pneumatic receiver (indicator, recorder, controller).

Appraisal

The bulk-modulus cell should find its most important applications (1) where comparatively rapid pressure change or viscous media would be unfavorable to manganin cells, (2) for pressure in the ranges 50,000 and 200,000 psi, (3) where moderate accuracy is desired, and (4) for rather fast instrument response. Table 1 shows comparative data.

The manganin gage, which is still indicated for pressures up 425,000 psi, or for accuracy of the order of 0.1% of full scale, is less rugged. Manganin gages can fail in liquid made viscous because of high pressure. Adjacent turns may rub together in the resistance coil; soldered connections may break; a protective bellows isolating the inert liquid surrounding the coil from the system liquid may be ruptured by excessive pressure surges.

The only effect of such a surge on the bulk-modulus cell (assuming rated pressure is not exceeded), would be to establish a transient pressure gradient along the probe.

At ranges below 75,000 psi, choice between a bulk-modulus cell, a manganin cell, a bourdon gage and a strain gage depends mostly on convenience, cost, accuracy and hazard. The bourdon is the simplest. The bulk-modulus cell and the strain gage are both characteristically remote-reading, though in the former it is advantageous to make the transmission line short (normally not over 500 feet). The bulk-modulus cell is distinctly superior, especially to the conventional bourdon and, to a lesser degree, to the strain gage and long helical bourdon in the matter of hazard. The probe is subjected only to hydrostatic compression and is not subject (at rated pressure) to fatigue which would result from repeated excessive strains. The cell body has no limitations on its proportions imposed by the functioning of the probe.

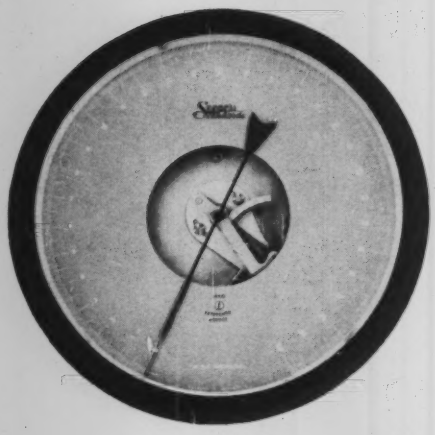
Table 1 presents range and accuracy of pressure-measuring instruments. The Heise Bourdon Tube Company manufactures gages good to 0.2%, but they are at present restricted to pressures of 50,000 psi. In standards work at the Harwood Engineering Company, Inc. the authors have been called upon to check the calibration of bourdon tubes by other manufacturers at far higher ranges. Some of these have ruptured before reaching full-scale deflection, some failed to return to zero by 5%, while a third group were in good calibration in the first third of the range, but over the rest of the scale might be in error by as much as 5%. On the other hand, strain-gage pressure cells have disclosed twice the accuracy claimed by the manufacturer.

The bulk-modulus cell (combined probe and transmitter), operating between zero and 200,000 psi, exhibits hysteresis of 0.5%. Calibration against a manganin gage up to 200,000 psi shows an overall accuracy for most cells of 1%. Selected probes may give results twice as good as this. Development continues, with the purpose of raising the accuracy of all cells to 0.5%.

Performance data regarding the effect of temperature on bourdon gages is lacking, but one specification mentions 1% error for a change of 50°F. Though strain gages are sensitive to temperature, it is a simple matter to provide compensation. A bulk-modulus cell has been tested at atmospheric pressure for temperature sensitivity by immersing it in melting ice until equilibrium was attained and then transferring it to a water bath at 170°F. This caused a reading shift of about 2% of full scale.

Acknowledgement

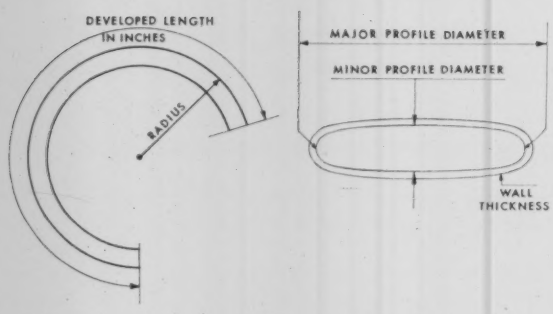
The authors acknowledge the cooperation of the staff of the Foxboro Company in the development of the bulk-modulus cell and the preparation of this paper, presented at 42nd AICE meeting, Atlanta, Feb., 1960.



PRECISION BOURDON-TUBE GAUGE

A survey of latest design and use factors and techniques, including principles, materials and recalibration. Latest product of continuing R & D is the "zero reference adjust" to insure calibration.

HANS SEEGERS, Seegers Instrument Company



Radius	1. Less tip travel 2. More torque 3. Higher fatigue limits
Developed Length	1. More tip travel 2. More torque 3. Higher fatigue limits
Wall Thickness	1. Less tip travel 2. Less torque 3. Lower fatigue limit
Minor Profile Diameter	1. Less tip travel 2. More torque 3. Lower fatigue limit
Major Profile Diameter	1. More tip travel 2. More torque 3. Higher fatigue limit

FIG. 1. EFFECT of increase in each dimensional factor.

Hans Seegers, a leader for nearly a half century in the greater utilization of the bourdon tube and precision accurate movements for pressure gauges, pioneered many advances to the art and science of pressure sensing and indicating instruments.

Arno and Erwin Seegers, sons of Hans Seegers, have enabled the company to take major strides in the design and production of Seegers Standards testing units.

Accuracy begins in the design of the gauge—primarily in the design of the bourdon tube. The bourdon tube, whether in the form of a "C," a spiral or a helix, is sealed at one end (the tip) and connected to the source of pressure at the other end. Because of the difference between the inside and outside radii, the bourdon tube presents different areas to the pressure. This differential area causes the tube to tend to straighten when pressure is applied, moving the bourdon-tube tip.

This tip travel is a nonlinear motion—less motion results from each additional increment of pressure. This nonlinearity poses an important calibration problem (which will be discussed in detail later, under "Calibration and Recalibration").

A bourdon-tube material should be readily weldable or solderable. It should form easily, it must possess perfect stability over an indefinite period of time, and it must be metallurgically and dimensionally consistent. A comparison of bourdon-tube-material properties is given in Table 1, using arbitrary ratings based on relative values.

Ni-Span C seamless tubing, drawn to the proper profile, is the proper choice for all but extremely corrosive applications. It is an age-hardened alloy of nickel, chrome and iron, to which titanium has been added. Its hysteresis is limited to 0.02% over a temperature range of −50° to +150°F with 25% or more cold work and heat treatment.

TABLE 1—RELATIVE RATINGS* OF BOURDON TUBE MATERIAL PROPERTIES

Material	Corrosion	Spring Rate	Temperature Coefficient	Hysteresis	Total
Trumpet Brass	1	2	1	2	6
Phosphorous Bronze	1	3	1	4	9
Beryllium Copper	1	6	1	6	14
316 Stainless Steel	6	2	1	2	11
Chrome Moly	1	4	1	4	10
Ni-Span C	5	5	6	5	21

*The higher the rating, the better the material property.

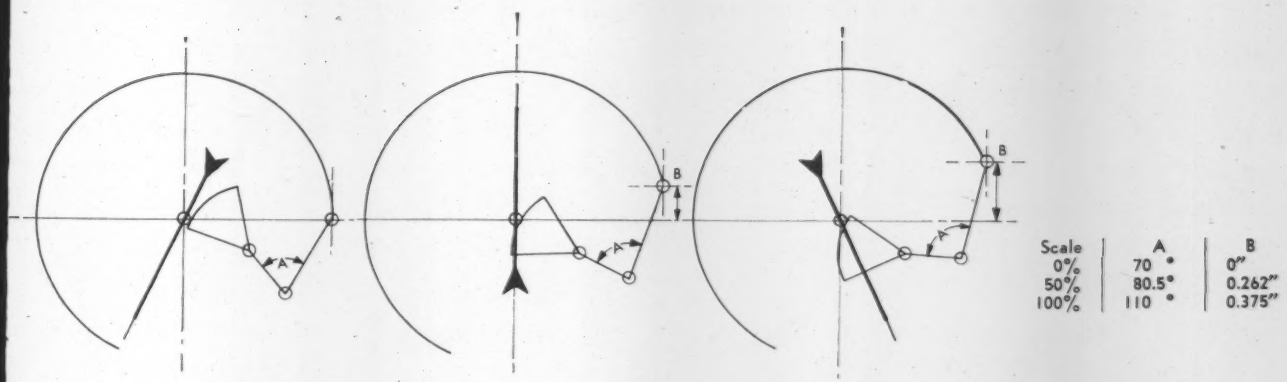


FIG. 2. **BOURDON TUBE,** link, and sector and pinion at 0%, 50% and 100% of scale.

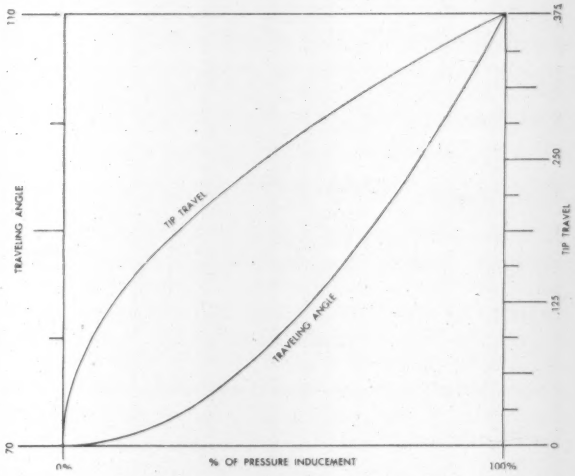


FIG. 3. **THE NONLINEAR** curves of tip travel and link angle compensate each other to give a linear pressure gauge.

Dimensional Factors

The bourdon-tube profile, or cross section, in relation to its developed length and radius of coil, determines the length and energy of tip travel. Fig. 1 lists the dimensional factors which influence bourdon-tube tip travel, tip energy, and fatigue limits. This chart assumes that all dimensions, other than the one being changed, are held constant.

The fatigue of a bourdon tube, generally noticeable only at the "zero" indication, results in inaccurate dial indications *over the full arc of dial calibration.* Such fatigue is caused primarily by pressures above rated limits. This fatigue factor can be compensated for properly only if the precision test gauge is equipped with a recalibrating device, as will be described later.

The Movement

The nonlinear output of the bourdon tube must be converted to linear rotational pointer response. This is done mechanically by means of a geared sector and pinion movement.* The movement should be as free of friction as possible. The sector must be balanced in order to maintain positive bourdon control, eliminate inertial drift, and prevent loading influence on the bourdon tube. Sector balance is obtained by applying an adjustable counterweight to the sector tail.

The motion of the bourdon tip is transferred to the tail of the movement sector by means of the connecting link. The design of the linkage must provide both ends of the link with 360° of adjustment in the plane of sector motion. These adjustments are used to calibrate test gauges to extremely close accuracy tolerances and linear response. The angle between the connecting link and the centerline of the movement sector is known as the *traveling angle.* The value of this angle changes at a nonlinear rate when compared to pressure applied to the test gauge.

Calibration and Recalibration

Figs. 2 and 3 demonstrate how the nonlinear curves of (1) the tip-travel versus pressure change, and (2) the traveling angle versus pressure change balance one another to give a linear pressure gauge. Fig. 2 shows the bourdon tube, link, sector, and pointer in three attitudes: at 0%, 50% and 100% of pressure inducement. If we plot the tip travel and traveling angle on a graph, we obtain the nonlinear curves of Fig. 3. Note that the mean of the two curves is a linear line. Pointer motion is now directly proportional, and linear, to the pressure inducement.

The process of adjustment and testing necessary to balance a precision test gauge is known as calibration. Should the bourdon tube of such a gauge

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*Recent research reveals that the newly developed Wickenberg Modified U.S. Fine Pitch gear design is the best gear form to use on precision test gauge sector and pinion movements. This involute tooth form eliminates excessive backlash. Simultaneously, it provides the absolutely smooth roll-on and roll-off required in a precision test gauge to smoothly and positively control pointer motion.

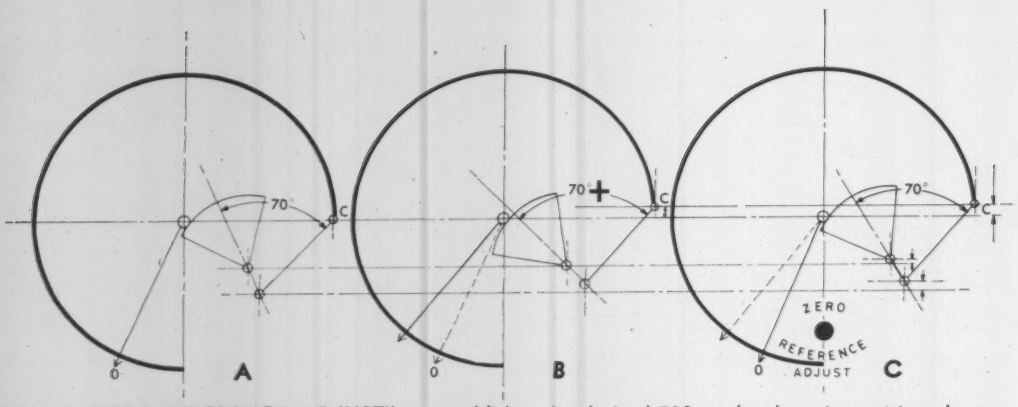


FIG. 4. "ZERO REFERENCE ADJUST" re-establishes the desired 70° angle when tip position changes due to bourdon fatigue. This establishes proper recalibration relationships.

fatigue, the fatigue could be compensated for—*if the gauge is equipped with a recalibrating device.*

Fatigue or shift is easily noticeable because the pointer is off "zero" under a no-pressure condition. When this occurs the "at rest" value of the traveling angle has been altered and the proportional relationship of the nonlinear values has been lost. The gauge must be recalibrated if it is to indicate accurately again. *This can be done only by reestablishing the balance between tip travel and traveling angle.* Any other method, such as shifting the dial until the "zero" is aligned under the pointer in its new position, only transfers most of the error to the full-pressure end of the indicating scale. Although this gauge would be accurate at "zero," the error would increase in proportion to the pressure applied.

The latest innovation in test gauges, and the result of years of research and development, is a recalibrating device which provides for the reestablishment of the proportional relationship between tip travel and traveling angle. This provides true recalibration because it restores original accuracy over the entire indicating scale. The device is known as *Zero Reference Adjust.*

It operates as follows: The dial is fixed in a permanent position; the "zero" scale indication is, therefore, fixed. It is utilized as a reference point in the process of recalibration.

The sector fulcrum can be repositioned so as to re-establish the desired angle A (70°) at the no-pressure condition. This adjustment is made by means of a cam which can be actuated with a screw driver from the front of the test gauge. When the sector fulcrum is repositioned, the traveling angle is changed and the pointer indication also is changed.

The "Zero Reference Adjust" re-establishes the "at rest" value of the traveling angle originally calibrated. If the bourdon tube of the test gauge should fatigue or shift, causing a noticeable pointer indication off "zero," the "Zero Reference Adjust" actuating cam is turned by means of a screw driver until the pointer again indicates "zero," as shown in Figure 4. Fig. 4A shows proper relations, as originally calibrated. Fig 4B shows how zero shift due to bourdon fatigue is accompanied by a change in traveling angle. Fig. 4C shows how Zero Reference Adjust reestablishes the original values of traveling angle and pointer zero.

Application

Test gauge users sometimes are not able to take full advantage of 0.1% full-scale accuracies available in advanced test gauges. This is often the case when the test gauge has been hydraulically calibrated and is used on a pneumatic application. Inaccuracies also are prevalent when the bourdon is filled with media of much higher specific gravity than the calibration media. Such inaccuracies can be averted if the manufacturer is apprised of the application situations.

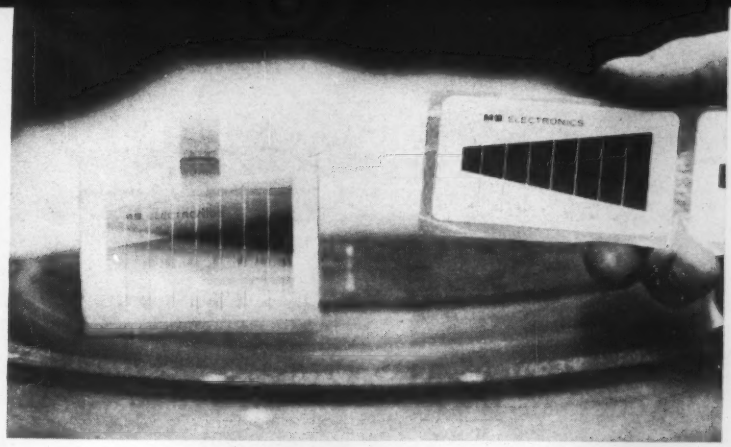
Other Features

The original accuracy of a precision test gauge and the ability to retain that accuracy are of primary importance. The instrument should be balanced for perfect calibration, be able to withstand overpressures ranging to 100% of rated pressure without permanent damage, and provide a zero-reference-adjustment recalibrating feature.

The pointer indication must be easily and accurately read. Newly developed anti-parallax mirrored dials eliminate reading error when used with razor-edged pointers. White calibration graduations on the face of the eye-ease green dial faces reduce eye fatigue. When a black razor-edge pointer is used to indicate over a green-and-white dial face, the accuracy and readability are increased because of the contrasting colors.

Bourdon tubes sometimes must be flushed if the test gauge is subjected to a contaminated, corrosive, or a variety of incompatible media. A bourdon-tube tip bleed valve, designed to exhaust the flushing media outside the case, is of importance in such situations.

Improvements and refinements in precision test gauges are the result of continuous research and development.



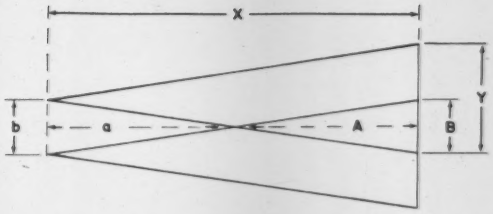


FIG. 1. OPTICAL WEDGE (right) and wedge in motion (left). Geometric relationships are shown at right.

The Optical Wedge

JOHN E. JUDD
MB Electronics

THE OPTICAL WEDGE has caught the fancy of engineers* as a means of measuring vibratory displacement. It offers tempting advantages—including negligible cost, direct readability and deceiving simplicity, which implies foolproof performance.

Physically, the wedge is a pressure-sensitive sticker that can be affixed to a flat surface on the object under test.

Theory

The wedge (Fig. 1) is essentially an isosceles triangle whose base is parallel to the axis of the input vibratory motion. The length of the wedge is graduated. The body of the triangle is usually black on a white background (or *vice versa*), although the wedge is not limited to this combination; other color combinations might enjoy some advantages.

When the wedge is subjected to rectilinear vibratory motion, two triangles are generated, one black and one white. The base line of each is opposite the other and is parallel to the input motion. The apexes of the two are joined. As the amplitude of motion is increased, the point where the apexes meet will move horizontally to the right in a proportional relationship. The position of the apex then can be interpreted on the horizontal graph in terms of total vertical movement of the wedge (double-amplitude displacement), as indicated in Fig. 1.

The geometric relationship is indicated in Fig. 1. In short, the motion of the apex along the horizontal axis is related by a constant to the double-amplitude displacement (b) of the wedge because

$$A/B = X/Y = a/b$$
$$a = b(X/Y)$$

As X/Y is a constant (K) for a given wedge:

$$a = Kb$$

Accuracy

Laboratory tests indicate that the accuracy of the displacement reading obtained from the wedge depends on many factors, including:

1. The magnitude of displacement.
2. Frequency of vibratory motion.
3. Fidelity of wedge dimensions and scale graduations.
4. The observer's experience and eyesight.
5. Optical effects such as the penumbra-like area around the apexes of the white and black triangle.
6. Non-rectilinear motion.
7. Other unknown psycho-physical phenomena.

In lab experiments, observed errors of 50% were not uncommon. The results of this cursory survey indicate that errors of less than 5 to 10% may be achieved if:

1. The observer is experienced.
2. The vibratory frequency is over 30 cps.
3. Vibration amplitude exceeds 0.100". Smaller amplitudes may be measured, but the degree of uncertainty increases rapidly. It is recommended that a person using such a wedge check himself against a known standard.

The optical wedge is a useful device for estimating vibratory amplitudes which exceed 0.3". A similar device for estimating smaller amplitudes has not been released (despite requests from customers), because tests indicate sizeable errors are possible in using such a device for low-displacement measurement. The search for a suitable configuration geared to handle measurements of a low magnitude is continuing.

The optical wedge is useful under certain conditions —but the engineer must be sure the wedge he is using is a "solution to his problem" and not a "problem in his solution."

*MB Electronics offered the item as a "giveaway" and 20,000 wedges have been distributed.

Selecting Bourdon-Tube Gauges

W. L. BUFFENMYER
US GAUGE
Div. of American Machine & Metals, Inc.

MOST CRITICAL COMPONENT of the bourdon pressure gauge is the bourdon-tube spring. The tube must meet a number of stringent design requirements determined by the nature of fluid being measured, pressure range, over-pressure, shock or vibration conditions, and pulsating pressures.

The bourdon tube is connected to the gauge movement by a tip and link arrangement. The type of tip connection required depends on the temperature and pressure to which the gauge is subjected. The motion of the bourdon-tube's free end is multiplied by the movement (Fig. 1) and changed into circular motion. Two plates separated by posts form the cage of the movement. Within these plates are the shaft-pivoted pinion and sector. The sector plate is extended beyond its pivot to receive the link from the bourdon-tube tip. The pinion meshes with the sector gear teeth. A hairspring between a post and pinion provides tension on the pinion to reduce backlash. The pointer mounts on the pivoted shaft.

A duplex gauge indicates two pressures on the same dial. This gauge has two complete measuring systems in one case and is used on air brake systems, water softeners and filters. A differential-pressure gauge indicates the difference between two pressures. The dial for this gauge can be graduated with zero at midscale.

Check list of factors in selecting a bourdon gauge include:

ASA Accuracy: .....
Application: .....
Case Material and Style: .....
Bourdon material: .....
Seals: .....
Range: .....
Size: .....
Pointer: .....
Dial Material: .....
Dial Graduation: .....
Damper: .....
Socket features: .....
Ring type: .....
Crystal type: .....
Special Mounting: .....

General Classifications

Pressure gauges are commonly classified according to *accuracy* (by ASA Standards), *case style*, and *end use*. The American Standard Indicating Pressure and Vacuum Gauges, B40.1-1939 (reaffirmed 1953) cantains basic gauge definitions and specifications and establishes accuracy limitations for the various gauge classifications.

Grade AA—test gauges: Error in pressure indication at any point on scale not to exceed ½% of maximum pressure of the graduated scale. Better accuracies, such as ¼% are available for more exacting measurements.

Grade A—high-grade commercial gauges: Error in pressure indication does not exceed 1% of scale range within middle half of scale, and 1½% along rest of the scale.

Grade B—commercial gauges: Error in pressure indication does not exceed 2% of scale range within middle half of scale and 3% along rest of the scale. These are widely used on original equipment.

Related to accuracy is repeatability. This is the ability of the gauge to give the same reading for same applied pressure time after time and may be more important than the actual accuracy.

Repeatability is far better than stated accuracy for most gauges.

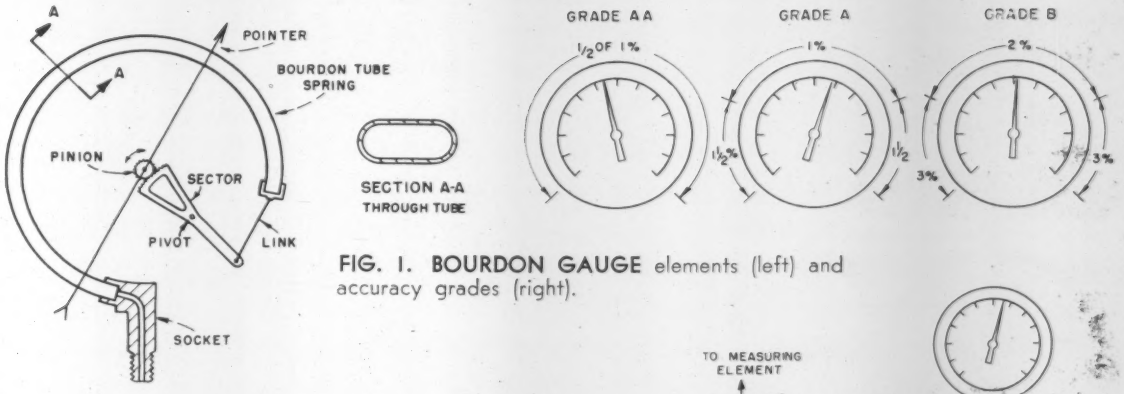


FIG. 1. BOURDON GAUGE elements (left) and accuracy grades (right).

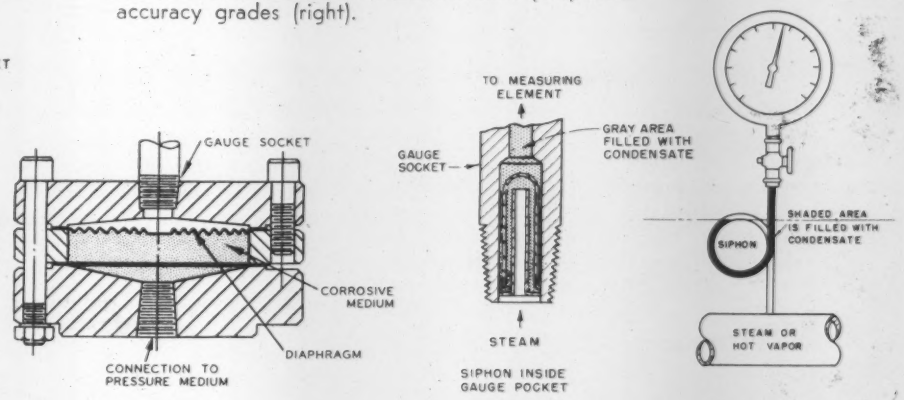


FIG. 2. SEALS include diaphragm, siphon inside gauge pocket, and single-loop siphon.

Bourdon Material

Tube spring materials depend on the application. Phosphor bronze grade A is used because of its strength, which is enhanced by cold working. This material cannot be heat-treated. Springs of this material are limited to vacuum, compound, and pressure gages up to 800 psi.

Beryllium copper is used for pressures from 1000 to 5000 psi.

Type 316 stainless steel provides corrosion resistance to many chemicals. It cannot be heat-treated to any degree. Tubes are available for pressures up to 10,000 psi. Material cost is comparable to alloy steels.

Type 403 stainless steel can be heat-treated and is suitable for pressure up to 20,000 psi. Tube walls for these pressures are heavier. Corrosion resistance is less than Type 316.

K-Monel is corrosion resistant to extremely sour oil or hydrogen sulfide and is used for pressures up to 20,000 psi.

Ni-Span C is practically unaffected by temperature changes. Effect on calibration is less than ¼% over a range of temperatures from −50 to +150°F. It is used in test gages and diaphragm pressure elements.

Seals and Sockets

Sometimes the process pressure medium cannot be brought into the bourdon because it may carry solids, may solidify in the gauge at room temperature, etc. One common method of separating the gauge tube from the measured medium is by a corrugated, corrosion-resistant diaphragm clamped between two support housings (Fig. 2). The upper housing is tapped and the male gauge connection screws directly into the housing. The bourdon tube and all space over the diaphragm is filled with a suitable fluid, which hydraulically transmits the measured pressure applied to the lower side of the diaphragm. A variety of such attachments is available to suit the various pressures and fluids, and the gauge and attachment should be selected as a unit.

When live steam or hot vapors are measured, direct connection to the bourdon tube may raise the tube temperature above the recommended level of 150°F. A single loop in the line (Fig. 2) prevents excessive temperature in the bourdon tube by condensed material. When the gauge is exposed to freezing temperatures, a low-freezing liquid is required in the bourdon tube and coil.

The socket connection can be selected either through the bottom of the case, the center of the back of the case, or low on the back of the case. Sockets can be bar stock, cast or forged. Socket type, material and connection should be specified.

Range

If the pressure will be fairly constant within relatively narrow limits, the range should be half again the expected pressure. Thus, if the working pressure is 200 psi, the selected range should be 0-300 psi.

With fluctuating pressures, defined as exceeding the steady pressure limits and having no cyclic regularity of variation, the maximum working pressure should not exceed one-half of the maximum value on the scale. This is a safety factor.

When pressures above and below atmospheric pressure are anticipated, specify a compound gauge with the zero point upscale. Such a gauge prevents

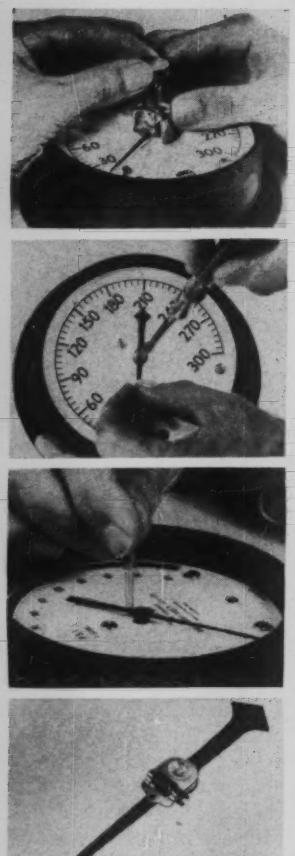


FIG. 3. POINTER types include (top to bottom) fixed Grade B, Grade A with screwdriver slot for adjustment, Grade AA test gauge with special tool for zero adjustment and Grade AA drawn case type.

damage if subjected to a sudden drop to vacuum.

If good readability is desired over a relatively small portion of a pressure range, use a suppressed-zero gauge.

Pointers

There are four types of pointers—fixed, adjustable, micrometer, and test gage (Fig. 3).

Fixed types—for economy, pointer is mounted tightly on pinion shaft. For either zero adjustment, liquid-column head compensation or preloading pointer, hub is lifted from shaft and repositioned.

Adjustable Type—for convenience and precision zero adjustment. Pointer is mounted with friction fit between pointer and hub and shaft. Adjustment is made by turning hub while holding pointer shaft firmly.

Micrometer Adjustment Type—for refined and easy adjustment. Usually available only on Grade AA gauges. Worm and pinion-type drive is mounted on pointer hub. Movement of worm gear causes vernier-like adjustment of pointer position.

Test Gauge Type—for precision measurements. The micrometer adjustment is of lighter construction than in the general micrometer type. Instead of the permanent worm gear, a special tool is used to engage teeth on pointer hub for adjustment.

Dials

Materials: Steel, brass, aluminum, solid or laminated plastic.

Graduations: Major, intermediate, and minor, depending on length of graduation line. Numerals are placed on major graduations. Number of minor graduations usually conforms to accuracy of gauge. For example, 100-psi gauge with 1% accuracy has minor graduations 2 psi apart because the gauge is accurate to ±1 psi.

Cases

Cases use either drawn (steel, brass, aluminum) or cast (iron, aluminum, brass, phenolic resin) materials.

Drawn steel is most common and economical materials. *Drawn brass* cases are used for corrosion resistance, decorative value, and anti-magnetic applications. For limited weight applications, *drawn aluminum* cases are used. Mounting styles include back flange, front flange, and beaded types.

Cast iron is generally used for ruggedness. *Cast aluminum* and *brass* cases are selected for the same applications as drawn cases of these materials. *Phenolic resin* cases provide excellent corrosion resistance. Mounting styles include back flange, front flange, and turret types.

When mounting a gauge—use a wrench on the socket; don't twist the case by hand.

Rings: Gage crystals are held against the case front by rings which are classified broadly into two categories: (1) appearance, such as beaded, flat, flared, and peaked, and (2) methods of attachment to the case, such as friction, slip, threaded, and hinged.

Crystals: Crystals are available in flat glass, beveled glass, cellulose acetate, shatterproof glass, acrylic plastic, and nonelectrostatic plastic.

Size

The nominal size of the gauge is the *inside diameter of the case at the face of the dial.* Available gauge sizes depend somewhat on the type of gauge, and are generally related to the degree of accuracy required. Drawn-case gauges are usually limited to dial sizes of 1½, 2, 2½, 3½, and 4½ inches.

Readability and accuracy do not basically influence the selection of drawn-case gauge sizes. However, relatively large numerals on large-size dials do ease the readability where, for example, there are physical limits on how close the observer can approach the gauge to read it. More pertinent are the limitations placed on space for equipment of panels.

For Grade A and Grade AA gauges, commonly available in sizes over 4½", the values of the smallest graduation do vary somewhat with size. In general, gauges 8½" and smaller have one set of limits and gauges larger than 8½" have another. These values are closely related to the guaranteed accuracies of the gauges.

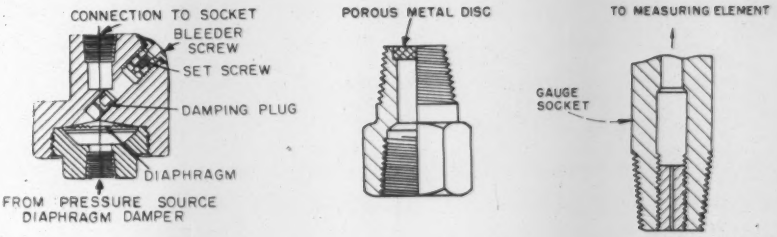


FIG. 4. PULSATION dampers include damping plug above diaphragm, porous disc, and small orifices.

Little is gained by insisting on finer gauge graduation than are compatible with the accuracy of the gauge. For example, with a Grade B gauge (2% accuracy over midscale), which has a range of 0 to 600 psi, readings accurate to within 12 psi of the true value can be obtained. However, actual minor graduation limits for this range are 10 psi. To specify smaller divisions would mislead persons reading the gauge.

Applications

End uses fall into roughly four groups—commercial, industrial, process and test.

Commercial gauges usually have a drawn case with ASA Grade B accuracy. They are used primarily on items for domestic use; household heating units, fire extinguishers, small pumps, and compressors. They have low unit cost and are devoid of refinements to simplify maintenance and repairs and are often called "throw-away" gauges.

Industrial gauges usually have cast case with ASA Grade A accuracy. They are used primarily for measuring steam, oil, and water-line pressures. These have limited adjustments for repair or maintenance.

Process gauges usually have cast cases with ASA Grade AA accuracy. They are used primarily for measuring pressures in oil, power, and chemical plants. They have long life and reliability, and provide for easy repair and maintenance.

Test gauges include all gauges of ASA Grade AA or better, regardless of applications.

Wear

Pulsating pressures, sudden shocks, and gauge vibration can seriously affect gauge accuracy and life. Pulsating pressure is simular to a fluctuating pressure but has a cyclic regularity. Rapid pulsations cause the gauge pointer to oscillate so that it is impossible to take a reading, and cause excessive wear of the gauge mechanism.

The simplest way to minimize the effects of pulsating pressure is to place a shut-off valve in the line to the gauge and throttle the valve until the pulsation just disappears. However, this invites trouble due to clogging of the small opening through the valve. Reliable protection against pusations can be obtained by using a *pulsation damper* on the gauge. A typical type (Fig. 4) employs a diaphragm seal. Above the seal and inside the bourdon tube, a nonfreezing hydraulic oil is used to dampen pulsations and permit reading of a mean pressure indication.

Other methods of damping include (1) throttling orifice screws which can be added to the gauge socket, (2) piston-type dampers which employ a movable piston, and (3) a baffle type with a series of orifices which can absorb pulsations in excess of 1 cps.

Such damping devices also prevent damage to the gauge from sudden and large pressure changes. To help prevent damage from shocks, some gauges include a zero stop in the movement rather than a dial pin which can cause a bent pointer if pressure is suddenly released.

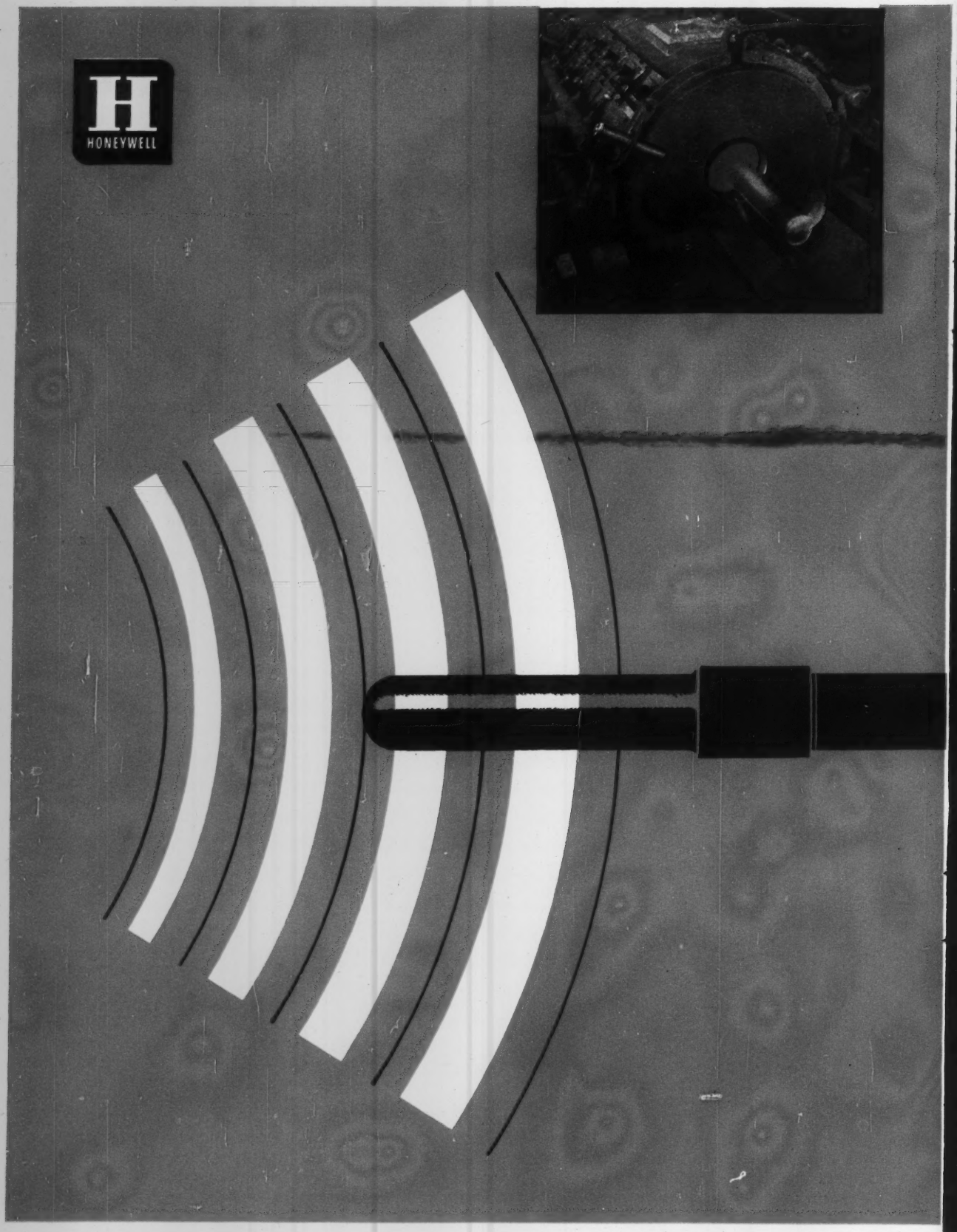
Most dial indicators are not designed to withstand continuous vibration. Hence, these gauges should be protected by suitable cushioning of the mounting, or by firmly attaching the gauge to a rigid support and using flexible tubing for the pressure connection.

Special Gauges

Gearless gauges are available for use on equipment such as portable air compressors and sprayers, where severe machanical vibration is generally present. These gauges have extra long bourdon tubes and a gearless movement which has direct linkage without sector or pinion. They meet Grade B standards.

Many end uses for gauges have given rise to class names which connote certain design features. One example is the ammonia gauge which has stainless-steel internal parts, including movement and socket, specifically designed to withstand ammonia and its fumes. Scale graduations show both pressure and ammonia temperature equivalents. The ASA standards recognize this specific gauge type and indicate that the gauge should be plainly inscribed with the word "ammonia."

Other gauge names which are self-descriptive of their service include refrigeration, air conditioning, boiler, welding, and sprinkler gauges. Generally, these are adapted or modified to meet specific codes or specifications established by particular industries.



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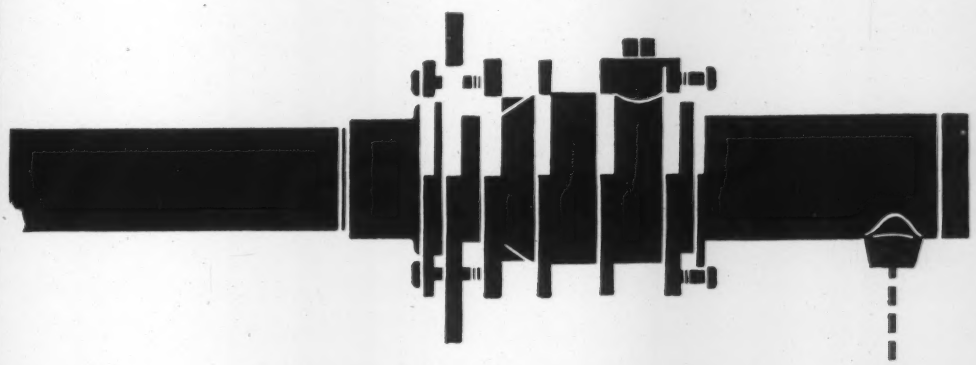


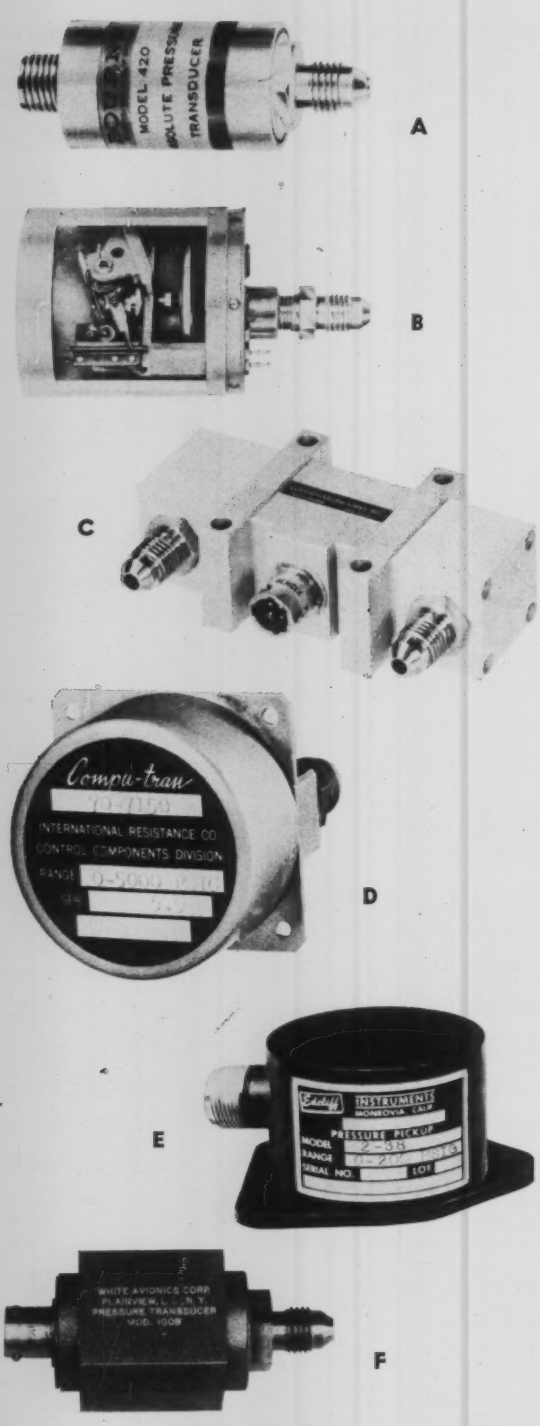


FIG. A. Many designs are available. A shows Bourns Model 420 absolute-pressure transducer, actual size, weighing only 4 ounces. B shows Fairchild TP-200 (transducer, pressure, 2" dia.). C is Colvin Type 401 d-p transducer. Compu-Tran (Div. of International Resistance Co.) Model 70-7150 is shown at D; ranges are up to 5000 psi. E shows Edcliff's Model 2-38 designed for 0-200 psig. F shows White Avionics Model 100B available with ranges to 300 psi. Servonic Model H-75 is shown in Fig. 3.

Potentiometric

HARRY N. NORTON

Convair-Astronautics Div.
General Dynamics Corp.

INCREASING use of direct-current instrumentation systems has necessitated major redesign of one of their essential components—the potentiometer-type pressure transducer. These new instruments now are used so frequently that analysis of their construction and operation can be helpful to engineers and designers contemplating their use.

Basic operating principle is shown in Fig. 1. The pressure to be measured is applied to a force-summing member (capsule, bellows, or bourdon tube) which moves a sliding contact (wiper) over an electrical resistance element. The voltage between the positive terminal of the element and the wiper is proportional to the applied pressure (more precisely, the *ratio* of the output voltage to the excitation voltage changes with the applied pressure). For most applications the change is linear. However, sine, cosine, logarithmic, exponential and other functions also are available.

Ranges

Pressure ranges of potentiometric devices can be classified arbitrarily as *low* (to 100 psi), *medium* (100 to 350 psi) and *high* (over 350 psi). This classification is based on the type of pressure-sensing element used (Fig. 2). Bellows or capsules (preferably) are used commonly for pressures up to 100 psi. Recent developments also have established a definite preference for use of capsules at pressure ranges up to 350 psi, although bourdon tubes have been used successfully in this medium range. Bourdon tubes are used almost exclusively above 350 psi.

Capsules

Capsules consist of two die-stamped dish-shaped corrugated diaphragms of spring alloy, welded together at their edges (Fig. 2).

Capsule materials include phosphor bronze, Inconel-X, and Ni-Span-C. The latter, a ferrous nickel alloy, is used most widely in transducers designed to operate in a varying temperature environment because of its excellent temperature-stability char-

Pressure Transducers

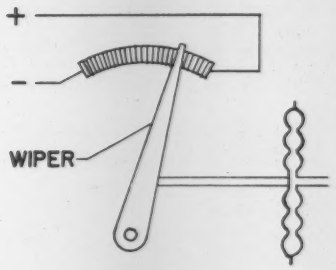


FIG. 1. PRESSURE in capsule or bellows pushes wiper across resistance elements.

Design refinements (including miniaturization, improved wiper contact techniques, vibration tolerance, and use of improved materials) have helped the potentiometric pressure transducer retain its popularity as a pressure sensor.

acteristics. Although high-quality capsules are commercially available, some instrument makers prefer to manufacture their own in order to cope more readily with necessary design variations.

In a typical design, an opening in the center of one of the diaphragms admits pressure into the capsule. A pushrod is attached to the center of the other diaphragm so that a change in applied pressure causes the pushrod to move longitudinally as the capsule expands. The useful motion obtained from the ⅜″-diameter capsule (used in many new "miniature" transducers) is approximately 0.04″. Some designs use two cascaded capsules to double this action.

Bourdon

The bourdon tube is a spring-alloy tube, elliptical in cross-section, closed at one end, and curved or twisted. Pressure in the tube tends to straighten it because of the difference in areas exposed to the pressure. If the open end of the tube is held rigidly in place, the closed end will move.

Some of the best transducer designs available use spiral (Fig. 2) or helical bourdon tubes (Fig. 3), which amplify the closed-end motion by the number of turns. Twisted bourdon tubes are not used in potentiometer-type pressure transducers as much as other types because the motion obtained is smaller.

Ni-Span-C alloy is the most popular bourdon tube material. Other alloys, notably some stainless steels, are used sometimes for special applications, provided their larger hysteresis error and their greater sensitivity to temperature variation is acceptable. Most instrument makers purchase tube stock and perform all other manufacturing operations (such as end-brazing or welding, winding and heat treating) at their own facilities.

Motion Factors and Acceleration

Potentiometer resistance elements vary in length from 0.3″ to 0.8″ in most transducers. Except for multi-turn bourdon tubes, the motion obtained

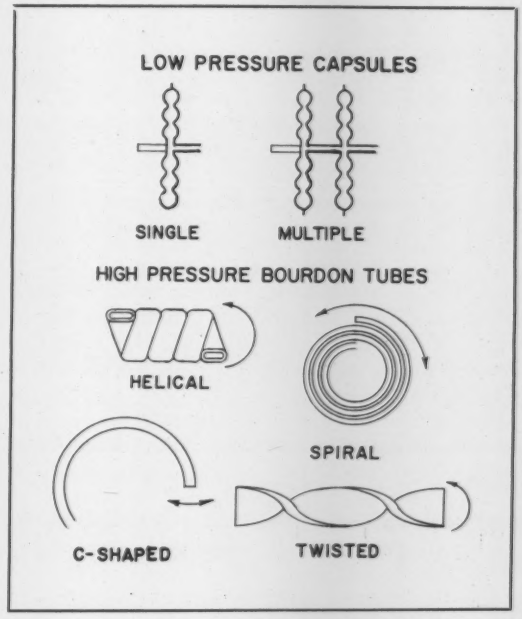


FIG. 2. CAPSULES are used for low pressures, bourdon tubes for high pressures. Spiral and helical bourdon forms are used to increase tip travel.

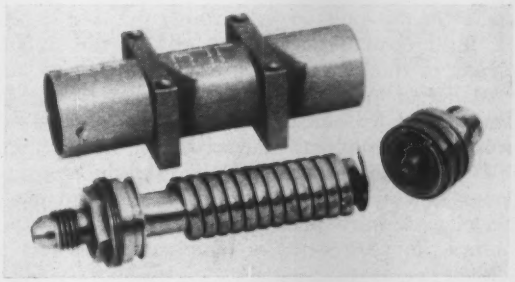


FIG. 3. HIGH-PRESSURE transducer uses helical bourdon tube; wiper on end of tube slides over resistance element on separate receptacle end assembly. (Photo courtesy Servonic Instruments, Inc.)

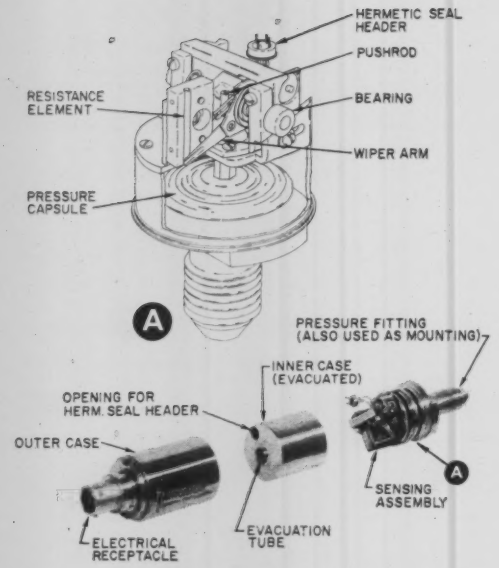


FIG. 4. LOW-PRESSURE transducer. Capsule sensing element and linkage are enclosed in evacuated, oil-filler inner case. (Photo courtesy Fairchild Controls Corp.)

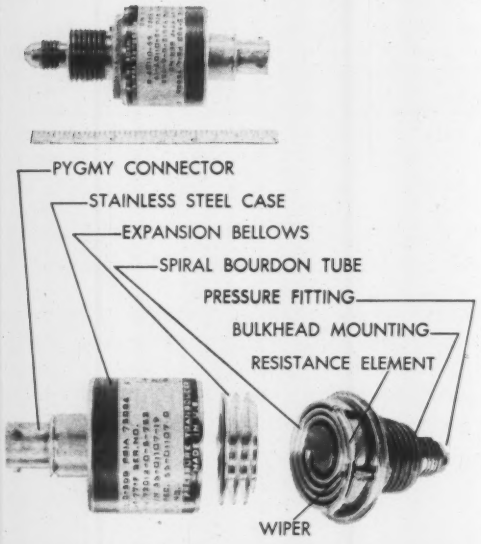


FIG. 5. HIGH-PRESSURE transducer. Wiper is attached directly to end of oil-damped spiral bourdon tube; expansion bellows compensates for temperature effect on damping fluid. (Photo courtesy Bourns, Inc.)

from the pressure-sensing element must be amplified mechanically to move the wiper over the full length of the resistance winding. This amplification usually is achieved by a lever-type linkage (Fig. 4).

Pivotal bearings (such as ball or jewel bearings) have to be selected carefully. They are designed for (1) low friction, (2) cycling endurance (without excessive wear), and (3) resistance to vibration. The free end of the linkage arm can be provided with an adjustable counterbalance weight to offset the effect of acceleration on the pushrod end of the arm. Use of spiral or helical bourdon tubes eliminates the requirement for linkages and removes the vibration, friction and backlash problems frequently associated with them.

A frequently used method of reducing the harmful effects of vibration is *oil damping* of either the linkage or the multi-turn bourdon tube. The damping fluid (usually a silicone oil) surrounds the linkage or the tube, as well as the wiper arm and resistance element. An expansion bellows (Fig. 5) compensates for changes in oil volume due to environmental temperature variations. Oil damping will cause the response of the transducer to be slower at low temperatures. However, oil-damped mechanisms have been shown to be satisfactory for most measurements at temperatures as low as −100°F.

Vibration can cause wiper lift-off from the element, producing noise spikes in the transducer output. Wipers usually are stamped from spring alloy, and grooved or dimpled to provide a narrow contact surface. Frequently, a precious-metal wire is fastened along the bottom of the wiper arm to reduce contact width and optimize the resolution of the instrument. A poorly designed wiper can cause troublesome lift-off and lateral excursion noise when excited at its own resonance frequency. Increasing the pressure of the wiper against the resistance element will tend to overcome this problem, but also can increase friction errors beyond acceptable limits and greatly reduce life.

Wiper shapes with protrusions resonating at different frequencies have been used with a fair amount of success. A double wiper construction with one contact below and one above the element has yielded excellent results because one-half of the wiper assembly always remains in contact with the element; thus noise due to discontinuities is reduced.

The Resistance Element

The resistance element usually consists of a length of precious-metal or nickel-alloy wire wound on a flat or round mandrel. Platinum or platinum-alloy wire, 0.5 to 2 mils thick, is used most commonly. Between 200 and 600 turns are wound around the mandrel, which can be an insulating material (such as ceramic, phenolic or micarta) or coated metal (such as anodized aluminum). The mandrel material is selected to match the temperature coefficient of expansion of the wire. Proper surface finish of the wound element improves life and reduces noise in the transducer.

Although wirewound elements are used in most potentiometer-type pressure transducers, other element designs are beginning to show promise. *Carbon-film* elements offer almost infinite resolution and can be short (less than 0.1″), thereby obviating need for a linkage. *Conductive-plastic* elements also have virtually infinite resolution and are so smooth that a wiper pressure too high for wirewound elements does not substantially increase errors due to friction. Various *metallic-film* elements also are being considered for use in pressure transducers.

Housings

Potentiometer-type pressure transducers weighing between 1½ and 5 ounces are now available in most ranges. A simple bulkhead-mounting thread can be used so that only one locknut and washer installs the instrument (Fig. 5). The new miniature units also can be provided with a pressure fitting and wrenching hex suitable for direct installation in a boss attached to a pipe, duct, tank or bottle. Another useful case design incorporates four mounting legs extending the full height of the transducer. Each leg contains a through hole so that up to three transducers can be installed in a stack.

Provisions for electrical connections are almost invariably made by hermetically-sealed receptacle, such as the Bendix-Scintilla PTIH "Pigmy" connector. Repeated tests have proved the absence of noise in the mated connectors even in the presence of severe vibration.

Differential-pressure, gage-pressure and absolute-pressure measurements call for a variety of transducer designs (Fig. A). Absolute-pressure transducers use an evacuated chamber, or a sealed chamber surrounding an evacuated capsule or bourdon tube. Gage-pressure units have a filtered vent to the external ambient atmosphere, rather than a vacuum. The linkage, wiper, and resistance element are usually isolated from the measured fluid, which may be corrosive.

Although requiring a more complex design, this also is desirable in differential-pressure transducers, particularly when the pressure differential between two mutually incompatible fluids must be measured. A typical design uses two bourdon tubes, each connected to a separate pressure source. The electrical element is rotated by one tube, the wiper by the other. Therefore, the transducer output is proportional only to the pressure difference between the two sources. A low-pressure version can contain two capsules connected mechanically be a pushrod. Motion of the pushrod will occur only if one capsule sees a higher pressure than the other. Motion of the pushrod is linked to the wiper arm.

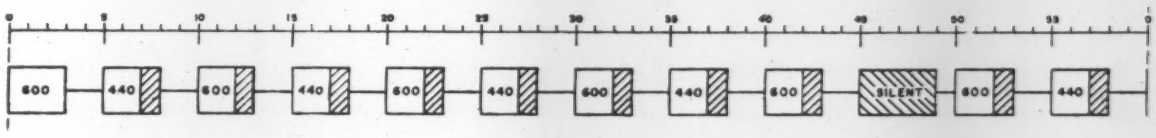
Typical of the new absolute-pressure transducers are the instruments shown in Figs. 4 and 5. These oil-filled transducers withstand vibrations up to 35 g at 2000 cps. Other types of low-pressure transducers are available that can stand the same amount of vibration without oil damping. Error due to variation in environmental temperature is approximately the same in both types. Recent modifications have pushed the vibration capability of some designs up to 50 g.

These improvements have established potentiometer pressure transducers as valuable instrumentation devices.

Changes in WWV/WWVH

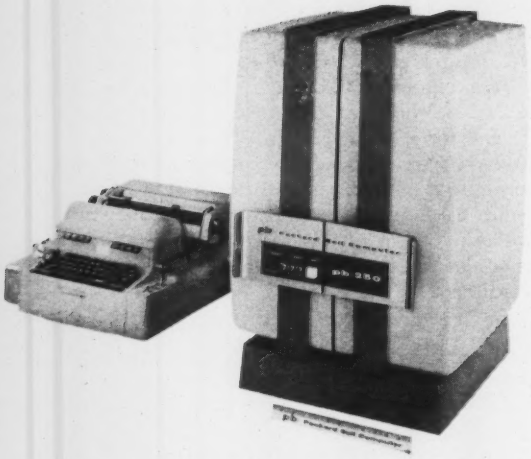
On January 1, 1961, at 0000 Universal Time (UT), the National Bureau of Standards retarded the time signals broadcast from radio stations WWV and WWVH by 5 milliseconds, and resumed broadcasting (on WWV) a special timing code which gives the day, hour, minute, and second in binary form. The 5-millisecond retardation brought the time signals of WWV/WWVH into closer agreement with other standardized-frequency broadcasting stations throughout the world and will help provide a more uniform system of time and frequency transmissions. This is needed in the solution of many scientific and technical problems in such fields as radio communications, geodesy, and the tracking of artificial satellites.

Illustration shows the WWV transmission for a 60-minute period, beginning at the start of each hour. The shaded 1-minute blocks represent a 36-bit 100-pps code that gives the day, hour, minute and second. The other blocks represent 600-cps and 440-cps tones.



THE COMPUTER AS A COMPONENT

MAX PALEVSKY
Packard Bell Computer Corp.



"Giant" features combined with "midget" size and price now permit a digital computer to be incorporated in many data systems.

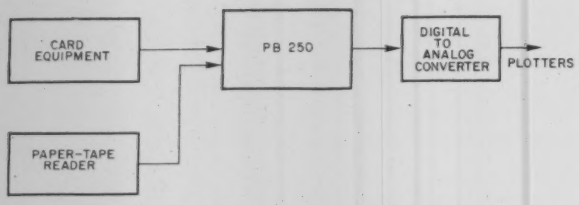


Fig. 1. Plotting system in which the computer selects data from cards and paper-tape readers, edits and scales the data, and delivers it to a D/A converter.

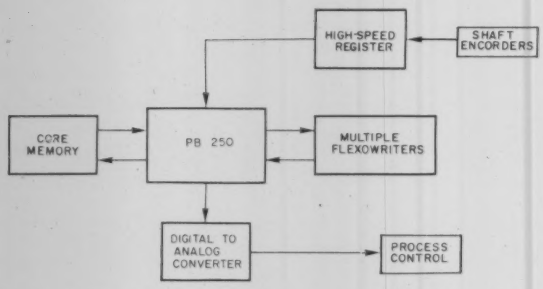


Fig. 2. In process control work, the data often is received from shaft encoders on potentiometers. This data can be used with a computer employing an external core memory (because of the large amount of data that must be stored), which feeds a logging typewriter and a D/A converter for curve drawing and control.

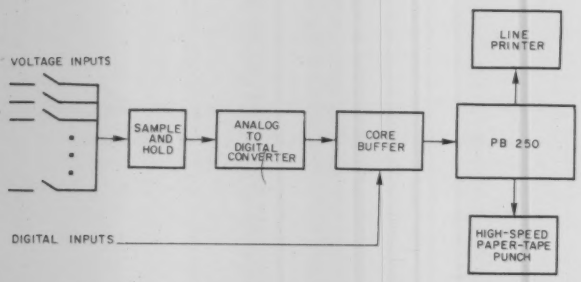


Fig. 3. In test work, a mass of data is accumulated in a small time. This high-speed data-gathering system uses a core buffer to store the information until it can be reduced by the computer.

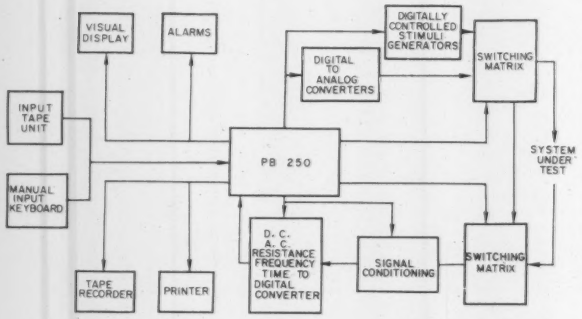


Fig. 4. In automatic checkout, the computer must select the test to be run, select the proper stimulus, select the proper response point, linearize the signals, perform the necessary computations, and perform self-checking procedures.

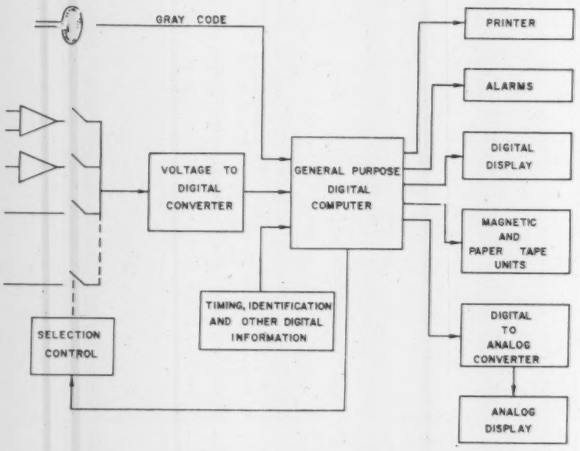
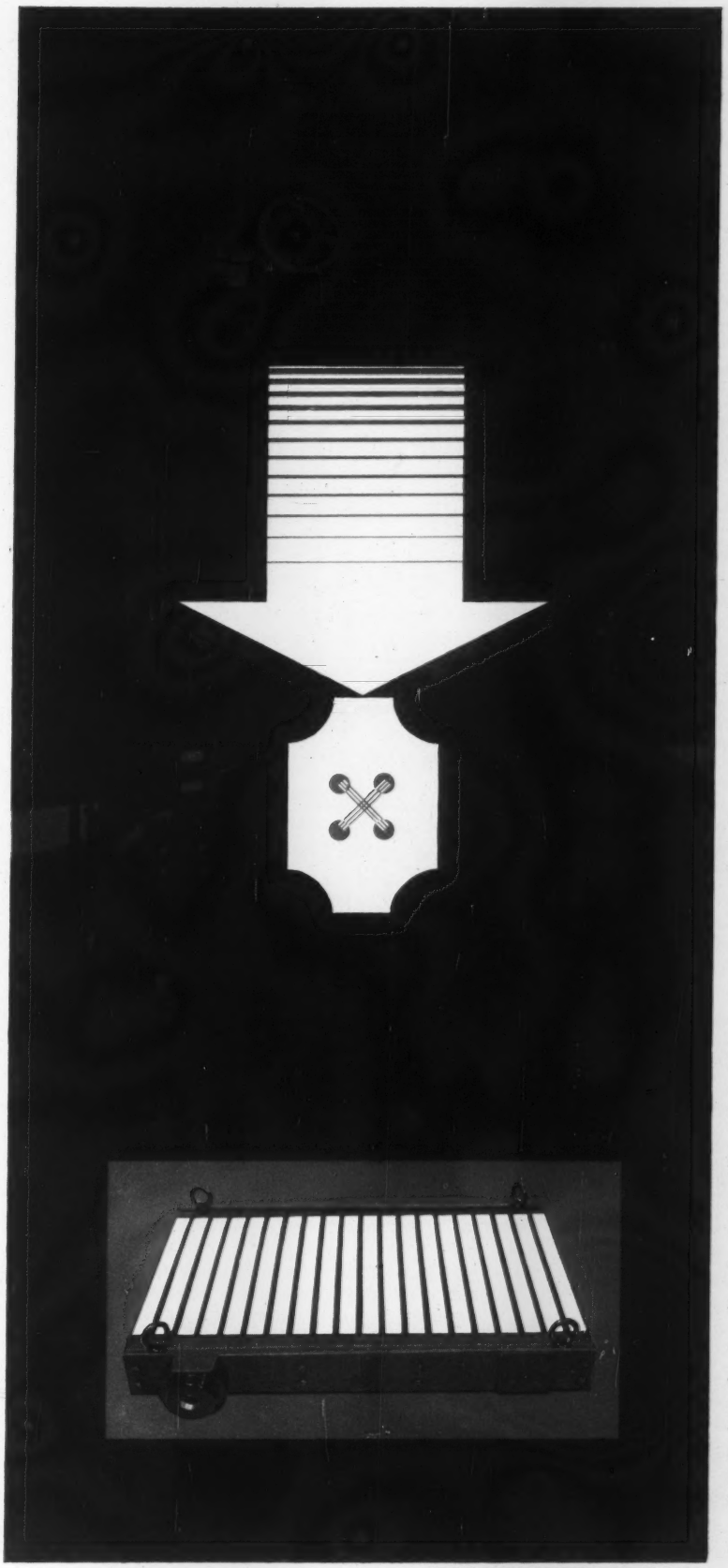


Fig. 5. A generalized data-gathering system, commonly used in process industries.



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Overload protection:
for transportation and handling equipment

Future planned applications include:
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CIRCLE 59 ON READER-SERVICE CARD

Generating-Station Computer Economics

R. A. BAKER, Public Service Electric and Gas Company, Newark, N. J.

As a result of a study (by a task force), we picture a type of computer control which has the following characteristics:

1. Automatic start-up.
2. Optimum operation by trimming set points.
3. Routine full-scale-equipment efficiency tests.
4. Operating records prepared daily, weekly, and monthly; plus data logging functions.
5. Better equipment protection by continuously monitoring operation, detecting and alarming abnormal and unsafe conditions, correcting such conditions, and taking the necessary steps to prevent equipment damage.
6. Automatic shut-down.
7. Independent instrumentation for manual operation. (In present stations, we have some 50 control circuits associated with the boiler, some 30 circuits with the turbine-generator, and roughly 100 control circuits installed on auxiliary equipment.)

Our statistics show that chance of catastrophic damage to a unit is once in every one hundred unit-years. We assumed the cost of repairs, capacity charge, and energy charge to be $1,000,000. Three years ago we experienced major damage to a turbine unit when the main bearings failed to receive lubrication; the cost of the outage was about $1,000,000, and we think that the kind of repetitive checking that a computer can make would have averted this. More recently, we had a furnace explosion which will cost approximately $4,000,000. Rapid sensing and fast computer action probably would have avoided the catastrophe. We are not claiming that the computer will avert all disasters, although its inherent ability to keep looking for trouble makes it possible. We have made our estimate on the basis of averting only one-half of the catastrophes; this has a capitalized value of $250,000.

Fuel costs can be minimized by heat-rate improvement due to continuous optimization of variables. Various estimates for savings run as high at 2%; our input-output tests show potential savings of at least 1%. To be conservative, we have taken credit for only ¾ of 1% savings on the unit. In addition, we believe there is an additional system saving of $20,000 due to dispatching load with more accurate and up-to-date information.

The value of the *reduced outage time* is estimated at $100,000. We assumed that, by being able to detect a malfunction or a failure sooner, damage would be less, and a shorter outage time would be required. Here again, to keep on the conservative side, we have included only one week day per year saving. The capitalized replacement energy charge for this one day is $80,000. With a computer, the unit would be put on the line faster; the value of this ability is $20,000.

We show a *capitalized saving* of $395,000 in personnel. Again, being conservative, we have eliminated only one shift position, at an annual cost of $24,000, or a capitalization value of $200,000. We anticipate eliminating two day-shift men in the Performance Department doing routine calculation for a capitalized saving of $133,000. An additional capitalized saving of $60,000 can be realized by eliminating the conventional acceptance test, periodic laboratory tests, and smaller routine station performance tests.

Savings of $1,215,000 plus some additional indeterminate amount are indicated with an additional outlay of $755,000. This gives a net capitalized savings of at least $460,000 through the step of automated station operation by use of a computer.

TABLE 1—ESTIMATED COST OF AUTOMATION, 342-MW UNIT

Computer and Associated Equipment		$560,000
Installation Labor		125,000
Total Direct Costs		$685,000
Field Overheads		45,000
Engineering and Design		75,000
Contingency		45,000
Total Installed Costs		$850,000
Computer Eliminates Need For:		
Data Logger	$90,000	
Automatic Dispatch Console	5,000	
		95,000
Total Additional Funds Required for Computer		$755,000

TABLE 2—CAPITALIZED SAVINGS BY COMPUTER AUTOMATION 342-MW UNIT

Reduced Possibility of Catastrophic Damage		$ 250,000
Fuel Costs Can Be Minimized		470,000
Unit	$450,000	
System	20,000	
Outage Time Can Be Reduced		100,000
Fewer Personnel Will Be Required		395,000
Operating	200,000	
Performance	135,000	
Testing	60,000	
Total Calculated Savings		$1,215,000

Plus Factors
1. Reduced Maintenance
2. Reduced Instrumentation on Future Units

Abstracts from paper presented at ISA Power Instrumentation Symposium, San Francisco, May, 1960.

VERSATILE WESTON RECORDER HANDLES 2 TO 24 POINTS—WITH EASY INTERCHANGEABILITY

Industry's leading recorder, the Weston Model 6702—has proved its versatility in more than two years of in-service operation. The first recorder of its kind, it accommodates up to 24 points in a single, compact unit. Number of points can be changed quickly. Accuracy is within ±0.25% of span or ±.025 mv on potentiometer.

Model 6702 features simplicity of design and performance. It has replaceable range standards and a plug-in amplifier. Printing and chart speeds are easily changed. Other advantages include the Weston D-PAK (T.M.) which eliminates standard cells, batteries and standardizing mechanisms . . . and a unique printed circuit switch is geared directly to the printing head.

Model 6702 is 39% smaller than the average multi-point recorder, and offers the convenience of rack mounting. It is designed and manufactured with traditional Weston craftsmanship to provide years of dependable, trouble-free service.

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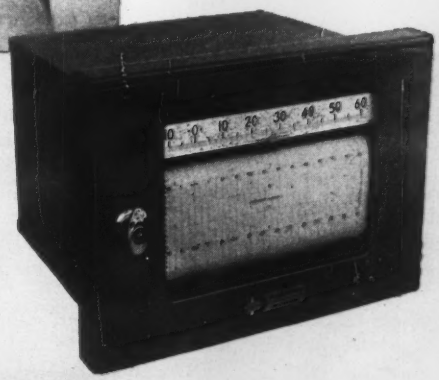

PROVED
in more than 2 years of service operation

Model 6702 uses full-size chart. Points: 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, or 24. Printing speeds: 3 to 60 seconds per point, readily changed. Operation: 115 volts, 60 cycles or 115 volts, 50 cycles.

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WESTON INSTRUMENTS DIVISION
Reliability by Design

CIRCLE 14 ON READER-SERVICE CARD

Digital Flow Blending

ROSS E. HUPP

Erie Pacific Division
Erie Resistor Corp.

A BIDIRECTIONAL COUNTER can perform flow rate control and fuel blending for the petroleum industry. Fig. 1 shows a typical application involving use of turbine-type flow transducers, optional factor scalers, preset counters, bidirectional counters, servo control amplifiers, electropneumatic controllers and valves to control flow rate.

Fuel flows from its storage tank to a manual shutoff valve and through a pump to the turbine flowmeter, which produces pulses in direct proportion to the flow rate. The electrical output signal from the flowmeter is amplified and fed to the "percentage set" preset, a 3-digit predetermining counter. This develops the ADD signal for bidirectional counter 500T. The counter also receives a pulse-train signal from the FLOW RATE SET OSCILLATOR, at its SUBTRACT input. There will be an output from 500T only when the ADD and SUBTRACT signals are not the same in frequency. Thus D establishes the output (total output from blend line). The % SET PRESET units (A and B) establish the percentage of the total output contributed by fuel A and fuel B. That is, if "% SET PRESET" A is set to 100%, only fuel A appears at output. If A and B are set at 20% and 80%, respectively, then the blend will contain 20% of fuel A and 80% of fuel B. If A is set at 20% and B at 20%, then the blend will certain 50% of A and 50% of B, but the output flow rate will be only 40% of that called for by the FLOW RATE SET OSCILLATOR.

Flow Rate Pacing

Consider that the system (line A only) is in equilibrium at 1000 gallons per minute. If the flow rate should increase (due to increased pump speed or other factors) then the rate of pulses generated by the flowmeter increases and the bidirectional counter begins to accumulate a positive count. The rate set oscillator output remains constant, and the result is a positive increase in d-c control voltage. The servo amplifier accordingly decreases the current to the electropneumatic control valve and the flow rate is decreased sufficiently to maintain the established flow rate.

At a setting of 100% the "percentage set" preset counter divides by 100, but when set to 10% the preset counter divides by 10. The flowmeter then need operate only at 1/10th its former speed to exactly offset the sustained pulse rate generated by

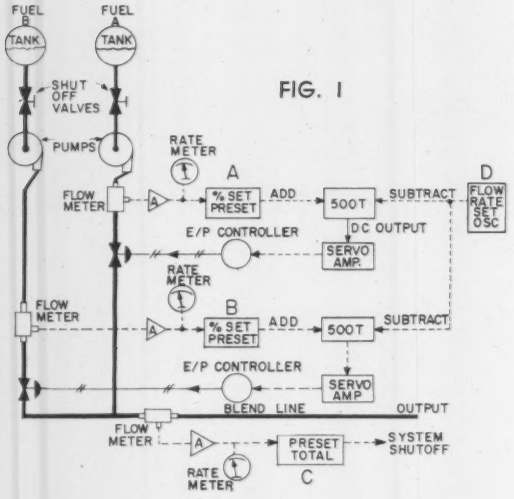

FIG. 1

the rate-set oscillator. Thus each ingredient is set to its desired percentage of the total blend. The sum of the percentages should be set in lines 1 and 2 to equal 100%. As both 3-digit preset counters are always set at less than 100% (99.9% maximum) the resolution of the system provides an accuracy approaching 1/10th of 1%.

The scale factor of the bidirectional counter can be varied to provide an output anywhere from 1/10 v dc per input-pulse discrepancy to 1 volt per pulse. The bidirectional counter's d-c output voltage can be monitored and adjusted so that total-blend flow rate matches the rate-set oscillator setting exactly. Once this adjustment has been made, the system will operate over a 10-to-1 flow range without any readjustment whatsoever. When indicated total-blend flow rate is equal to the rate set by the master oscillator, the system is functioning properly.

The d-c output voltage of the bidirectional counter is sensitive to $\pm$ 1 pulse difference between the ADD and SUBTRACT lines. This is integrated by the slow response of the servo control valves. Even though the instantaneous flow rate varies somewhat, the average value over a relatively long period of time is equal to the desired rate.

Individual rate meters are also provided on each line for monitoring individual-ingredient and total-blend flow rates. Each rate meter developes a d-c signal proportional to flow rate and indicates flow rate in the units desired.

NEW

E-W Time Code Generator

Model 6190

...Makes time with Atomic Accuracy

Solid State EW Timing Code Generator Uses Atomchron Input

Epsco-West's new Model 6190 Time Code Generator is accurate, flexible, and reliable. In conformance with recommendations of the Interrange Instrument Group (IRIG), the Model 6190 generates a 36 bit 100 pps code, a 28 bit 2 pps code and a 20 bit 1 ppm code. Other outputs are available to drive digital printers, digital tape recorders, strip-chart recorders, oscillograph galvanometers, synchronizing signals and mixed tones of precision frequencies.

The EW Model 6190 is one of a complete line of solid state, modular time code equipment which includes time code generators, time code translators, timing terminals, and universal tape search equipment.

Complete technical information on the Model 6190 Time Code Generator is ready now. Call your nearby knowledgeable Epsco-West engineering representative or address Dept. 54.

Advanced Circuitry Stems From Transistor Know-How

In the Model 6190, all pulse widths and timing are directly derived from the digital dividers and time accumulator by diode matrices. No one-shot circuits are used. Information is not transferred from one register to another. No "stub" counter chains are used. These design features provide absolute synchronism and minimum distortion. Modulation occurs precisely at the true positive going zero-axis point on the carrier.

Epsco-West *First in Data Control*

A Division of EPSCO Inc., Cambridge, Mass.

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7

KEY SPECIFICATIONS

Input Signal

100 kc, 1-volt RMS, to impedance of 10,000 ohms. An internal frequency standard may be supplied as optional equipment.

Outputs

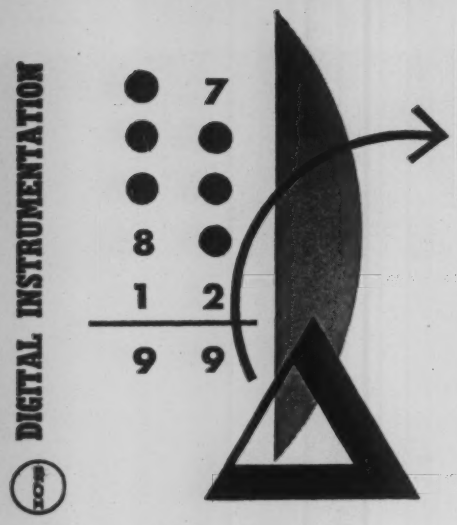
1. Logic Output, 36-bit parallel BCD (—12v for binary "zero", 0-volts for binary "one").
2. 20-bit, 1 ppm on 100 cps carrier, 1 hour time frame.
3. 28-bit, 2 pps on 100 cps carrier, 1 minute time frame.
4. 36-bit, 100 pps on 1000 cps carrier, 1 second time frame.
5. Three outputs of the 100 pps, 2 pps and 1 ppm modulation pulses at 2 milliampere max. for driving galvanometers.
6. Relay closure at 1 ppm, 28-bit, 2 pps code, closure for pulse durations.
7. 1 pps at 1-volt, synch pulse, accessible front and rear.
8. 1 pps relay closure of 200 ms.
9. Mixed tones output; 100kc, 50kc, 25kc, 12.5kc, 6.25kc, 3.125kc sine waves.

Elapsed-Time Range
399 days 23 hr. 59 min. 59 sec.

Accuracy
Dependent only on reference oscillator.

Size
19" wide by 10½" high x 18" deep.

CIRCLE 60 ON READER-SERVICE CARD



CODE CONVERSION BY NOR LOGIC

JOHN M. BOSWELL Radiation, Incorporated

Fourteen NOR elements perform binary-to-decimal conversion.

A BINARY-TO-DECIMAL converter (Fig. 2) is often required when going from a working code to a decimal readout device. That is, the input is binary, and the output desired is decimal. Equivalent binary and decimal numbers are shown in the last two columns of Table 1.

The function of NOR elements 1, 2, 3, and 4 (Fig. 2) is simply to make available $\overline{A}$, $\overline{B}$, $\overline{C}$, and $\overline{D}$.

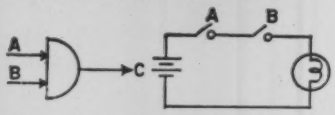
The input to NOR 5 (A, B, C, D) causes an output of $\overline{A} \upsilon \overline{B} \upsilon \overline{C} \upsilon \overline{D}$, which is equivalent (by DeMorgan) to $\overline{A}\cdot\overline{B}\cdot\overline{C}\cdot\overline{D}$, the condition necessary to produce a decimal "zero" output.

The condition for a decimal "one" output is $A\cdot\overline{B}\cdot\overline{C}\cdot\overline{D}$, which is produced by NOR 6, with inputs $\overline{A}$, B, C, D. The output is $\overline{\overline{A} \upsilon B \upsilon C \upsilon D} = A\cdot\overline{B}\cdot\overline{C}\cdot\overline{D}$.

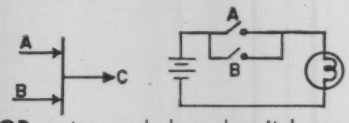
Table 1 gives the required inputs and outputs to produce each of the numbers.

Fig. 2 represents one decade of a binary-to-decimal converter, which is the same as 1 decade of a binary-coded decimal system. For straight binary work, Table 1 shows the addition of 6 more NOR elements (under the dotted line) with appropriate A-B-C-D inputs that would produce decimal numbers up to 15, with the four inputs shown.

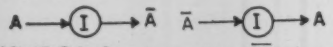
REFRESHER ON SYMBOLIC-LOGIC FUNDAMENTALS



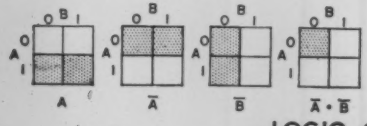
AND gate, symbol, and switch analogy for A AND B = C, written as $A\cdot B = C$.

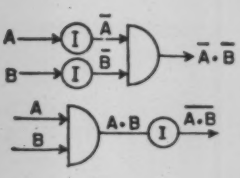


OR gate, symbol, and switch analogy for A OR B = C, written as $A \upsilon B = C$.

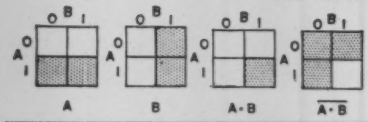


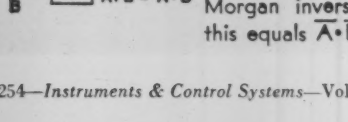
SYMBOL for inverter. $\overline{A}$ means NOT A.





LOGIC CHARTS show truth of statements $\overline{A}\cdot\overline{B}$ (top) and $\overline{A\cdot B}$ (bottom). They are not the same. Implementation of these expressions also is shown.





NOR ELEMENT has output NOT (A or B). By DeMorgan inversion, this equals $\overline{A}\cdot\overline{B}$.

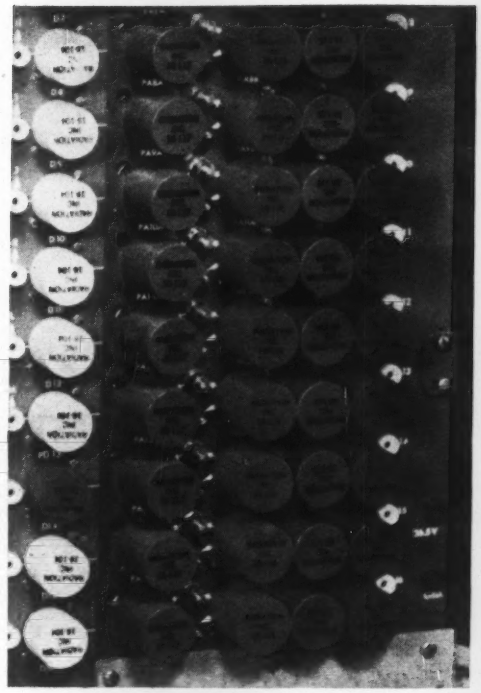


FIG. 1. NOR ELEMENTS in a typical configuration.

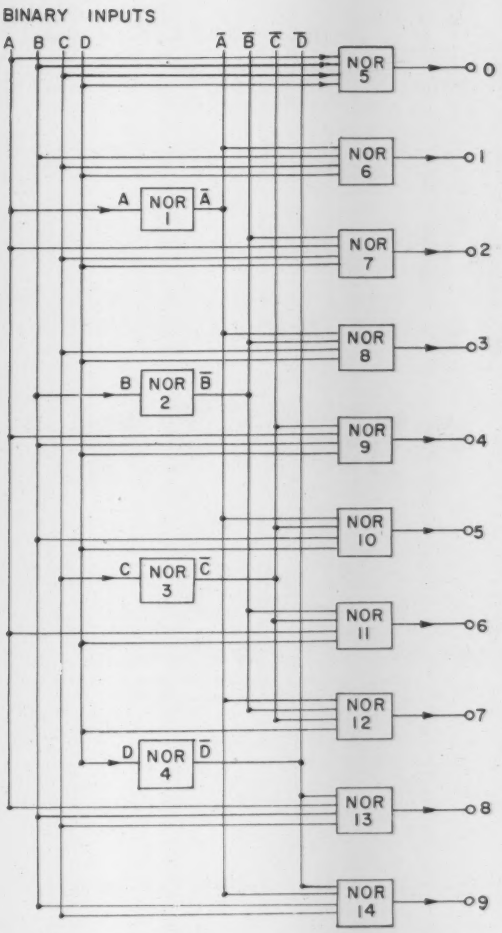


FIG. 2. FOURTEEN NOR elements form a binary-to-decimal converter.

TABLE 1—INPUTS AND OUTPUTS OF CODE CONVERTER

	INPUTS	NOR OUTPUT		BINARY		DECIMAL
NOR-5	A,B,C,D	$\overline{A \vee B \vee C \vee D}$	$= \bar{A} \cdot \bar{B} \cdot \bar{C} \cdot \bar{D}$	= 0000	=	Zero
NOR-6	$\bar{A}$,B,C,D	$\overline{\bar{A} \vee B \vee C \vee D}$	$= A \cdot \bar{B} \cdot \bar{C} \cdot \bar{D}$	= 0001	=	One
NOR-7	A,$\bar{B}$,C,D	$\overline{A \vee \bar{B} \vee C \vee D}$	$= \bar{A} \cdot B \cdot \bar{C} \cdot \bar{D}$	= 0010	=	Two
NOR-8	$\bar{A}$,$\bar{B}$,C,D	$\overline{\bar{A} \vee \bar{B} \vee C \vee D}$	$= A \cdot B \cdot \bar{C} \cdot \bar{D}$	= 0011	=	Three
NOR-9	A,B,$\bar{C}$,D	$\overline{A \vee B \vee \bar{C} \vee D}$	$= \bar{A} \cdot \bar{B} \cdot C \cdot \bar{D}$	= 0100	=	Four
NOR-10	$\bar{A}$,B,$\bar{C}$,D	$\overline{\bar{A} \vee B \vee \bar{C} \vee D}$	$= A \cdot \bar{B} \cdot C \cdot \bar{D}$	= 0101	=	Five
NOR-11	A,$\bar{B}$,$\bar{C}$,D	$\overline{A \vee \bar{B} \vee \bar{C} \vee D}$	$= \bar{A} \cdot B \cdot C \cdot \bar{D}$	= 0110	=	Six
NOR-12	$\bar{A}$,$\bar{B}$,$\bar{C}$,D	$\overline{\bar{A} \vee \bar{B} \vee \bar{C} \vee D}$	$= A \cdot B \cdot C \cdot \bar{D}$	= 0111	=	Seven
NOR-13	A,B,C,$\bar{D}$	$\overline{A \vee B \vee C \vee \bar{D}}$	$= \bar{A} \cdot \bar{B} \cdot \bar{C} \cdot D$	= 1000	=	Eight
NOR-14	$\bar{A}$,B,C,$\bar{D}$	$\overline{\bar{A} \vee B \vee C \vee \bar{D}}$	$= A \cdot \bar{B} \cdot \bar{C} \cdot D$	= 1001	=	Nine
NOR-15	A,$\bar{B}$,C,$\bar{D}$	$\overline{A \vee \bar{B} \vee C \vee \bar{D}}$	$= \bar{A} \cdot B \cdot \bar{C} \cdot D$	= 1010	=	Ten
NOR-16	$\bar{A}$,$\bar{B}$,C,$\bar{D}$	$\overline{\bar{A} \vee \bar{B} \vee C \vee \bar{D}}$	$= A \cdot B \cdot \bar{C} \cdot D$	= 1011	=	Eleven
NOR-17	A,B,$\bar{C}$,$\bar{D}$	$\overline{A \vee B \vee \bar{C} \vee \bar{D}}$	$= \bar{A} \cdot \bar{B} \cdot C \cdot D$	= 1100	=	Twelve
NOR-18	$\bar{A}$,B,$\bar{C}$,$\bar{D}$	$\overline{\bar{A} \vee B \vee \bar{C} \vee \bar{D}}$	$= A \cdot \bar{B} \cdot C \cdot D$	= 1101	=	Thirteen
NOR-19	A,$\bar{B}$,$\bar{C}$,$\bar{D}$	$\overline{A \vee \bar{B} \vee \bar{C} \vee \bar{D}}$	$= \bar{A} \cdot B \cdot C \cdot D$	= 1110	=	Fourteen
NOR-20	$\bar{A}$,$\bar{B}$,$\bar{C}$,$\bar{D}$	$\overline{\bar{A} \vee \bar{B} \vee \bar{C} \vee \bar{D}}$	$= A \cdot B \cdot C \cdot D$	= 1111	=	Fifteen

Ask Your *FISHER/MAN* How To

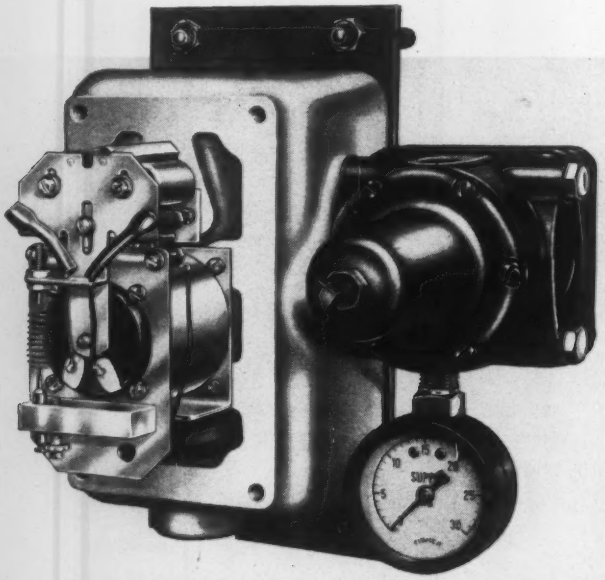
SPEED THE INPUT SIGNAL to the CONTROL VALVE

FISHER

TYPE

543

ELECTRO PNEUMATIC TRANSDUCER



Available with or without a pneumatic valve positioner

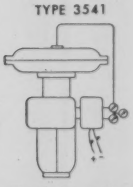
Here's an electro-pneumatic transducer developed for use in electrical control loops where the final control element is pneumatically operated. Explosion proof design makes it ideal for use under hazardous conditions. Input signals may range from 1 to 5 ma. through 10 to 50 ma.... output from 3 to 15 psi through 6 to 30 psi. Built-in volume relay permits direct operation of the pneumatic actuator from the Transducer. No extra relays or boosters needed. Relay can be serviced independent of electrical assembly. Unit is completely reversible by reversing input leads and rezeroing.

If you want additional information on the Type 543 Electro-Pneumatic Transducer write Fisher Governor Company.

TYPICAL CIRCUITS		
Input Current	Load Requirements of Controller	Actual Internal Resistance of Transducer
1 to 5 ma dc	3,000 ohms maximum	2,500 ohms ±125 ohms
1 to 5 ma dc	12,000 ohms ± .5%	12,000 ohms ± 50 ohms
10 to 50 ma dc	500 ohms maximum	57 ohms ± 4 ohms

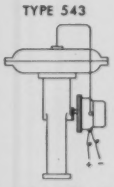
PERFORMANCE DATA	
Linearity	1% of full range
Air Consumption Rate	2 SCFH with 15 psi output pressure
Resolution Sensitivity	.05% of input range
Frequency Response	Complete frequency response data with Fisher topworks available

TYPE 3541



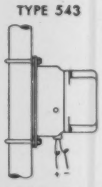
Electro Pneumatic Controller Mounted on Control Valve

TYPE 543



Transducer Mounted on Control Valve

TYPE 543



Transducer Mounted on Stand Pipe

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD... CHANCES ARE IT'S CONTROLLED BY...

FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / London, England

CONTINENTAL EQUIPMENT CO. DIVISION, Coraopolis, Pennsylvania

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SINCE 1880

CIRCLE 61 ON READER-SERVICE CARD

PART I: MEASUREMENT OF APPLIED ACCELERATION

Accelerometer Calibration

Accurate accelerometer calibration presents two problems—one comprises accurate measurement of the applied acceleration, the other the accurate measurement of the corresponding accelerometer response. The first part of this discussion deals with the measurement of applied acceleration. Accuracy factors are discussed for constant linear acceleration (g and rotary accelerator), nonconstant linear accelerators (shock and sinusoidal vibrators), constant angular accelerators (rotary units with constant angular acceleration or deceleration), periodic angular accelerators (pendulum or vibrator).

LAWRENCE MOSKOWITZ
Schaevitz Engineering

CONSTANT LINEAR ACCELERATION can be developed by at least two relatively simple methods. The first uses the earth's constant gravitational field g, the second uses a horizontal rotary accelerator.

Using Gravity

Acceleration can be varied from 0 to 1 g* by inclining the sensitive axis of the accelerometer 90°. Accurate determination of the acceleration applied along the sensitive axis of the accelerometer depends on accurate determination of the angle of inclination. Fig. 1 illustrates an accelerometer mounted on a rotatable platform for this purpose.

The component $g(\sin\theta)$ is applied along the sensitive axis of the accelerometer. The normal component $g(\cos\theta)$ cannot be ignored unless the accelerometer has zero crosstalk. At zero acceleration applied along the sensitive axis, any acceleration output signal will be due to crosstalk. The crosstalk factor is expressed as a fraction of a g per g of cross acceleration.

Accurate angle determination is a mechanical problem most easily solved by an accurate dividing head. Reference is to a true horizon that can be established by a low-range accelerometer. The accelerometer should have its sensitive axis parallel to its mounting base, and provide external zero adjustment. Then the accelerometer base is placed on the surface to be checked and adjusted until its output is a minimum. This will allow observation on the low range of a meter. The high sensitivity of a low-g accelerometer will provide a large change in meter reading for a small change in angle. The accelerometer is rotated on the surface; the surface is level when the accelerometer output is *constant* for any azimuth orientation. Note: Sensitive axis of the accelerometer need not be exactly parallel to its base, or to the surface, in order to establish a level surface by this method.

Whether an accelerometer's actual sensitive axis is parallel to its base (or to the sensitive-axis line on the accelerometer housing) can be determined by using the upper and lower parallel surfaces of a true horizontal surface (Fig. 2). Place on upper surface (U). Seismic mass displacement is proportional to sin θ. This displacement is cancelled by sliding the LVDT core with respect to the seismic mass core.

*g is 32.16′/sec²—at Princeton, N. J.

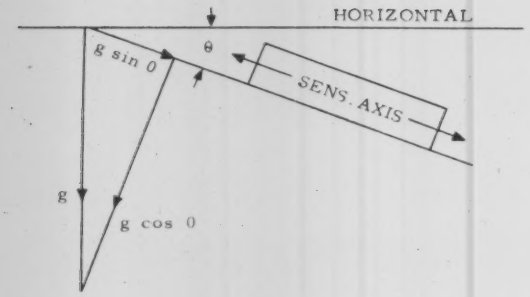


FIG. 1. ACCELEROMETER, on rotatable platform, with sensitive axis inclined.

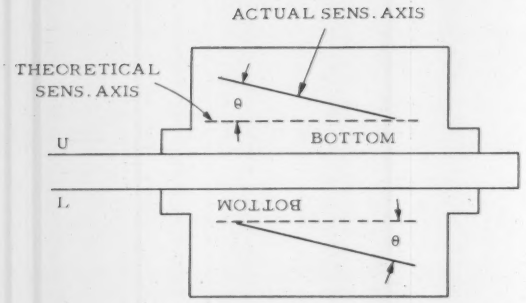


FIG. 2. USE of upper and lower surfaces to test whether sensitive axis of accelerometer is parallel to its base.

Then place the accelerometer base against lower surface (L). The seismic mass is displaced in the opposite direction. The difference in electrical output is now proportional to 2 sin θ, and is denoted as E_m. If known accelerometer sensitivity in volts per g is E_g, and the output corresponds to 2 sin θ displacement, sin θ (for small angles) can be calculated by:

$$\sin \theta = E_m/2E_g$$

$$\theta = \sin^{-1}E_m/2E_g \qquad (1)$$

Use of Rotary Accelerator

The second method of applying constant linear acceleration is by a horizontal rotary accelerator (Fig. 3).

The accuracy of determining the applied acceleration is a function of the accuracy with which (1) rotational speed and (2) radial distance (to the center of seismic mass) are determined. The applied acceleration is:

$$\text{Acceleration (g units)} = 0.000028416RN^2 \qquad (2)$$

where R is in inches, N is in revolutions/minute.

The error in the determination of speed can be either a discrete quantity (such as ± 0.1 rpm) for digital readout, or a percent of the speed reading for analog readout. Speed error is in rpm when a frequency generator is coupled to the rotating platform and speed is read by a digital device such as a counter. Speed error is a percent of reading when a frequency generator is read by a stroboscopic device. (One such device, the Stroboconn, is rated at $\pm 0.05\%$.)

A serious disadvantage of the digital readout is that average speed during the counting interval is indicated rather than instantaneous speed. Since a practical accelerator must be a variable-speed device, constant speed is usually not easy to obtain. However, it is not imperative that absolutely constant speed be available, provided the instantaneous speed can be determined accurately at the time the accelerometer response is measured, which is possible with the analog-readout device.

Usually the error tolerance of length measurement is a discrete quantity, such as $\pm 0.001''$, rather than a percent of the length reading.

When the speed error is a percent of reading, the best accuracy for acceleration is obtained when the accelerometer is at the maximum radius that can be accommodated by the accelerator. For example, if a 10″ radius is accurate to $\pm 0.001''$, and speed is measured stroboscopically with an accuracy of $\pm 0.05\%$, the over-all accuracy would be $\pm 0.11\%$. For a 20″ radius, also accurate to $\pm 0.001''$, the over-all accuracy would be $\pm 0.105\%$. For small accuracies the acceleration accuracy is given by the expression:

Accelerometer Accuracy (%) =
Radius accuracy (%) + 2 x Speed accuracy (%)

The applied acceleration also depends on whether the accelerometer's sensitive axis coincides with the accelerator radial line—the sensitive axis should be on a line with the center of rotation. Also the seismic mass of an accelerometer may have an appreciable displacement when accelerated by a centrifuge.

Assume a specific acceleration (A) is to be gener-

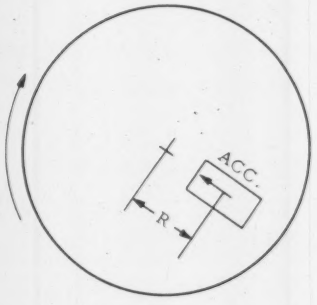


FIG. 3. THE HORIZONTAL rotary accelerator imposes a constant linear acceleration.

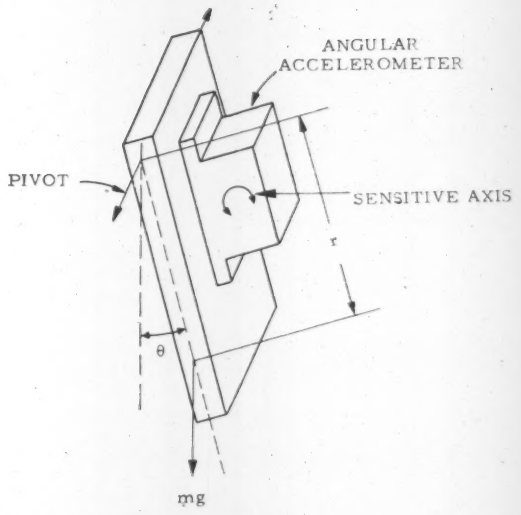


FIG. 4. ACCELEROMETER on pendulum, which imposes a non-constant angular acceleration.

ated. If D is the seismic mass displacement in inches per g, and R_o is the radial distance to the center of seismic mass for zero speed, then X_a, the desired speed reduction factor is:

$$X_a = \sqrt{R_o/(R_o + DA)} \qquad (3)$$

Calculated rpm is multiplied by X_a to get a figure for speed that will produce the desired acceleration. D is not usually a published accelerometer parameter, but the natural frequency (F_n) is. The following expression gives D in terms of F_n:

$$D = 9.8/F_n^2$$

Accurate accelerations can be generated if a source of a single constant speed is available, such as a centrifuge driven by a synchronous motor. The radius for a specific acceleration (A) can be found by:

$$R_o = A(1 - KDN^2)/KN^2$$

where $K = 0.000028416$

The zero-g center of seismic mass can be located by moving the accelerometer along a radius of the rotating accelerator platform until output is zero. The center of seismic mass now coincides with the center of rotation, even if the sensitive axis did not coincide exactly with a radial line. The center of seismic mass can be determined to at least $+0.001''$ in this manner. At 1000 rpm an acceleration of 0.028g will be acting on the seismic mass when its center is displaced $0.001''$ from the center of rotation.

Non-Constant Linear Acceleration

Controlled non-constant acceleration can be either intermittent or periodic.

Intermittent acceleration includes shock acceleration—useful mainly for environmental testing rather than for calibration purposes. This will not be considered.

Sinusoidal periodic acceleration is particularly suitable for dynamic calibration and testing of accelerometers. This is used chiefly in determining the *damping ratio* and *natural frequency* of accelerometers. The applied acceleration is given by the expression:

$$A = 0.10225f^2D \qquad (4)$$

where A is peak acceleration (in g units), f is frequency (in cps), and D is peak displacement (in inches).

Damping ratio is determined by measuring the accelerometer response to constant-amplitude sinusoidal acceleration at its natural frequency and at a lower frequency. If the responses are designated as R_n and R_x, the damping ratio is:

$$D.R. = \frac{1 - (F_x/F_n)^2}{2\sqrt{(R_x/R_n)^2 - (F_x/F_n)^2}} \qquad (5)$$

When $F_x = 0$ cps, this simplifies to:

$$D.R. = R_n/2R_x$$

The measurement of R_n and R_x will be discussed in Part 2—Measurement of Accelerometer Output.

A convenient method of measuring the acceleration input (and consequently being able to maintain constant amplitude) involves the use of an accurate *velocity transducer* to measure the velocity of the shaker platform. Many electronic vibrators are normally supplied with such a velocity pickup. The vibrator displacement (D) is given by the expression:

$$D = K \sin \omega t \qquad (6)$$

where K is peak amplitude.

The vibrator peak velocity (V) is:

$$V = \omega K$$

And the vibrator peak acceleration (A) is:

$$A = \omega^2 K = \omega V$$

Thus for A to remain constant as ω is varied, V must vary inversely. This is done conveniently by applying the output of the velocity pickup to a precision voltage divider and applying the divider output to the vertical d-c input of a scope. For a low-frequency acceleration the divider is set to a convenient low output and the scope gain is adjusted for a convenient pattern height. As the frequency is increased the required velocity voltage decreases. This would cause the scope pattern to diminish in height. If the divider is now set to a value equal to the original setting multipled by the ratio of the higher frequency to the lower, the scope pattern height should be the same as before. The excitation of the electronic vibrator is adjusted as required to attain the original height. The acceleration level can be changed as desired, at any given frequency, by setting the divider to a value equal to its setting at the original level multiplied by the ratio of the original level to the new level and then varying the vibrator excitation to attain the original height. For example:

G Level	Scope height	Frequency	Divider
1	10	10	0.1
1	10	20	0.2
1	10	88.2	0.882
4	10	88.2	0.2205

The accuracy of acceleration levels by this method is better than 1%. The main factor is the accuracy with which the scope pattern height can be observed. This is improved if the maximum height permitted by the screen size is used.

Constant Angular Acceleration

Constant angular acceleration is not easily produced for calibration purposes. If a mass is rotated about an axis at a constantly *increasing* angular velocity (constant angular acceleration), constantly increasing radial forces are produced. The maximum safe velocity is limited. The higher the angular acceleration the sooner the safe limit is reached, thus limiting the observation time for higher accelerations.

An alternate approach would be to bring the rotating mass to maximum speed over a long period of time (which would use less power), and use the *deceleration* available by braking. However, no such commercially-built equipment is now available.

Non-Constant Angular Acceleration

Non-constant angular acceleration can be intermittent (shock) type or periodic. Periodic low-frequency angular acceleration is easily produced by pendulum and can be used for accurate scale-factor calibration provided the frequency is in the order of $0.1f_n$.

If m and I_o are the mass and moment of inertia respectively of a pendulum accelerometer system (Fig. 4), and r is the distance from the center of rotation to the center of gravity of the system, the period T of such a pendulum for small amplitude of oscillation is given by the expression:

$$T = 2\pi\sqrt{I_o/mgr} \qquad (7)$$

The torque Q, and hence the angular acceleration α, is a function of θ:

$$Q = mgr \sin\theta = I_o\alpha \qquad (8)$$

By substituting 7 in 8:

$$\alpha = 4\pi^2 \sin\theta/T^2 = 4\pi^2 f^2 \sin\theta \qquad (9)$$

Starting the pendulum (including the accelerometer), and counting the swings for a one- or two-minute period provides a measure of f. For a torsion pendulum:

$$\alpha = 4\pi^2 f^2 \theta \qquad (10)$$

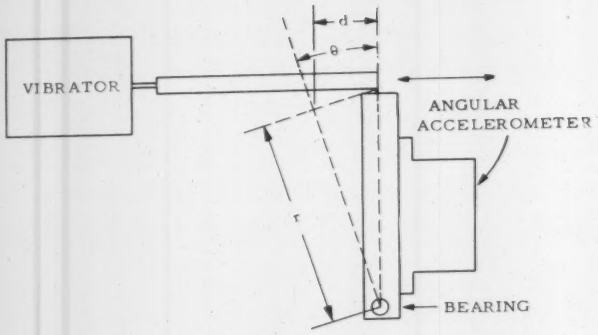


FIG. 5. LINEAR VIBRATOR with rocker arm can impose a non-constant angular acceleration.

The advantage of the torsional pendulum is that f can be increased easily for larger accelerations because it is proportional to the torsional spring constant. In the compound pendulum f is proportional to mgr/I_o and cannot be conveniently increased since an increase in m and r will also increase I_o

A third method of applying periodic angular acceleration is by adding a rocker arm to a linear vibrator (Fig. 5).

In Fig. 5 the angular acceleration is:

$$\alpha = 4\pi^2 f^2 \theta \qquad (11)$$

For small angles: $\sin\theta = \theta = d/r$ (12)

Hence:

$$\alpha = 4\pi^2 f^2 d/r \qquad (13)$$

As r is constant for a given system the angular acceleration is proportional to f^2 and d, just as for linear vibration. Consequently, the procedure for these measurements with linear vibration can be adopted completely for applying constant angular acceleration with variable frequency.

Up to 3° the sine of θ differs from θ by less than 0.1%. For available displacements of 0.2″ and radius of 12″, the sin is 0.2/12 = 0.0166, corresponding to an angle of less than 1°. Thus the accuracies available with this method are excellent. (It is important that the pivot bearing be loaded to remove all play.)

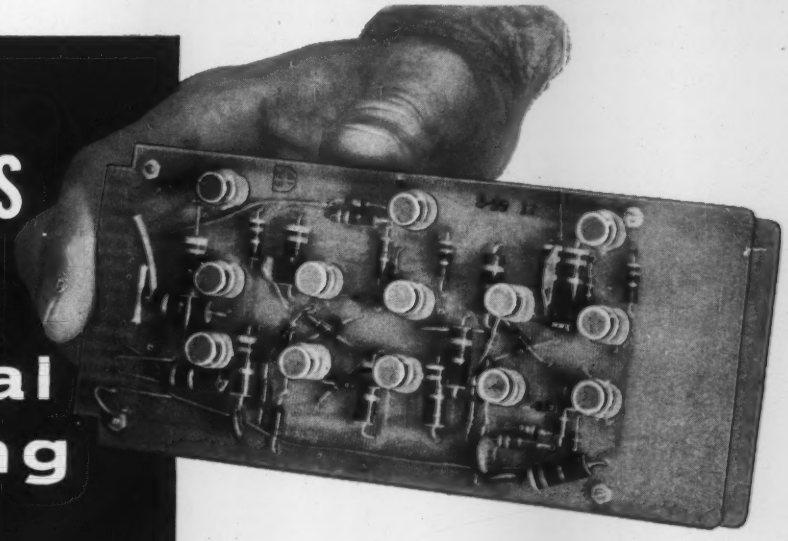
ADDITION TO OUR SURVEY OF VOLTAGE REFERENCE SUPPLIES

Dynage, Inc., offers the "Volt-Cal" d-c voltage calibrator, a precision source of millivolts for use with potentiometers or calibration instruments. The supply is available with ranges of 0-10, 0-100 and 0-1000 mv. The circuit uses a regulated power supply (Zener diode network) connected through a fixed resistor to a 10-turn precision potentiometer with one thousand dial divisions.

Voltage stability is 0.01% for line voltage change of 94-140 v; temperature stability is 0.002%/C degree from 0 to 40°C; linearity is 0.05%; over-all accuracy 0.1% of full scale at any setting. Weight is 5 lbs. Battery-powered models also are available.

BREAKTHROUGH!

100 Mc/s *Direct* Decimal Counting



Announcing Eldorado's Model 1050 Solid State Gated Counter—a triple purpose instrument

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- **Time Interval Measurements with 10 nanosecond resolution***
- **Frequency Measurements to 100 Mc/s without heterodyne conversion***

BASIC DATA

Counting and Frequency Measurement

STORAGE 10^9 counts (9 digits)
MAX. COUNTING RATE 100 Mc/s
DOUBLE PULSE RESOLUTION Better than 10 nanoseconds
TYPICAL INPUT PULSE REQUIREMENT +4 volts into 50 ohms
TYPICAL START/STOP PULSE REQUIREMENT —4 volts into 50 ohms

For Time Interval Measurement

EXTERNAL TIME REFERENCE Trigger requirements same as for input pulse above or will operate on 5 volt peak-to-peak 100 Mc sine wave

APPLICATIONS—The multipurpose Model 1050 is particularly suited for use in weapon or satellite systems, advanced electronic measurements, and nuclear research. Among specific areas of application are studies of missile velocity, acceleration and trajectory; space vehicle tracking; shock wave investigations; radar, telemetering, and communications; frequency stability, phase, and phase shift measurements; pulse width, rise, fall and duty cycle measurements; semiconductor studies; astronomical measurements; nuclear flight time, coincidence, and particle burst studies.

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For details on the new logic, contact your Eldorado engineering representative for Bulletin D-1050, or write us directly. Demonstrations at your convenience. Please address Dept. 54.

*When used as a time interval meter, Model 1050 requires an external oscillator for time reference; when used as a frequency meter, it requires an external time base. Eldorado can supply both. The Eldorado Model 1060 Time Interval Meter with same resolution has a built in oscillator for time reference.

Eldorado Electronics

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CIRCLE 62 ON READER-SERVICE CARD

How "permanent" are permanent storage media?

Permanent Storage Media

PAUL C. CONSTANT, JR.
Midwest Research Institute

A NUMBER of different media commonly are used in computer systems for the storage of data, some of which are considered to be *permanent* forms of storage—that is, the medium is capable of holding data in their original form for an indefinite period of time. Those which are most often used are (a) *punched cards*, (b) *paper tape*, and (c) *magnetic tape*. Other means of storage which are not used as often, but which still fall within the classification of permanent storage, are those using photographic methods.

Normal wear and tear make all permanent storage media wear out. Permanency is a function of many variables.

Punched Cards

The use of punched cards began in 1889 when Dr. Herman Hollerith patented the Hollerith punched card. The machinery which was invented and constructed for the application of the punched card later became the basis for the International Business Machines Corporation. This corporation, which was organized in 1911, has used punched cards as a means of input and output of information to and from its calculating machinery from its beginning. As a consequence of this application of punched cards and the ubiquity of IBM computing equipment, the medium of the punched card has been widely accepted as a permanent means of storage.

Punched cards have been known to age rapidly. However, there are cases where an organization has used the same set of punched cards for permanent storage of information for 25 years. Of course, in such cases, the cards have had a minimum of use with automatic computing machinery and have had the best of care in their handling and storage. The main factors to be considered when using punched cards for a permanent means of store are:

1. Proper temperature and humidity control in the area in which the cards are to be stored;
2. Proper packing of cards in storage; and
3. Minimum usage of the cards with computing machinery.

Paper Tape

As with punched cards, paper tape material seems to age rapidly. In order to increase the life period for this storage medium, proper temperature and humidity control should be maintained in the area in which the tape is stored, and minimum usage of the tape should be exercised. In addition, proper handling of the tape at all times is important.

Magnetic Tape

Magnetic recording tape was adopted by the German broadcasting stations more than 20 years ago, and has been professionally used in America for approximately 13 years. It has been universally accepted by broadcasting stations throughout the nation.

In 1952 magnetic tape recording was first adopted, on a commercial basis, in computing systems. During the past 8 years, this medium has been widely accepted as an excellent means of auxiliary storage for various computers. It also has been accepted by numerous organizations with computer centers as a permanent means of storage of information. Among those are the Bureau of Census, the Department of Agriculture, and several life insurance companies.

The most important environmental factors affecting magnetic tape during storage are *heat* and *humidity*. The effects of these factors include permanent deformation of the backing film, deterioration of the backing film and/or the oxide-binder material, and magnetic "print-through."

The acetate and polyester films which are used for backing on the magnetic tape have a positive coefficient of thermal expansion and coefficient of humidity expansion. The oxide-binder material (the material which holds the backing film to the magnetic tape) has coefficients different from either type of base-film material. Therefore, a gross change in humidity and/or temperature causes a differential expansion which creates stresses that cause "cupping" (a tendency to curve toward the coated surface). An excessive amount of differential expansion causes permanent deformation of the film. Moisture is considered to be the controlling factor in this physical distortion of the film. A relative humidity of 40% to 60% and an ambient temperature between 70 and 75° F are optimum conditions for storage of magnetic tapes.

Winding

It is extremely important that tape with acetate film be *properly wound* on the reel during storage because the acetate film tends to assume a permanent set after prolonged storage. The main factor to be considered in winding the tape on a reel for storage is the speed at which it is wound. High rates of winding usually result in a poor pack of air entrapment between layers of tape, and inadequate or varying tape tension which tends to accelerate a permanent set of the film. It is therefore advantageous to adopt a procedure of rewinding tape at a rate slower than the normal high-rate-rewind speeds of most tape units. An alternate method would be to have the tape wound on a high-precision reel which has reduced clearance between the flanges and the edges of the tape.

Plasticizer

Another item of importance with respect to long-term storage is related to the loss of *plasticizer* that is a constituent of most oxide-binder formulations. A familiar example of this phenomenon is the hardening of a shower curtain after a period of time. The same thing happens to the acetate base of magnetic tapes and to the binders of many tapes. In addition to the increased stiffness imparted to the backing material by the loss of its plasticizer with time (accelerated by heat), the coating becomes brittle and the oxide-adhesion properties are impaired. Most manufacturers of magnetic tapes have now completely eliminated volatile plasticizers from the coating formulation used in their tapes. With the elimination of the volatile plasticizer, there is a greater assurance of permanent and constant flexibility and adhesion of the coating, even after the acetate backing has lost its plasticizer. This elimination of the volatile plasticizer is of even greater importance if polyester film is used as the backing material; otherwise, although the polyester remains stable, the binder can deteriorate to the degree that it will be destroyed the first time it is used after prolonged storage.

Print-through

Layer-to-layer signal transfer (magnetic *print-through*) is a problem that plagued some of the early tapes and exists to some degree in all tapes. It should not cause, however, a reclassification of the magnetic-tape medium to one of the nonpermanent means of storage unless recorded tape is exposed to unfavorable conditions. These conditions are long storage at a high temperature and/or an excessively tight wind. It is advisable to store the recorded tape under the proper environmental conditions and to periodically rewind the rolls to release any layer-to-layer signal transfer.

Print-through is actually a recording process in which the oxide particles of one layer of tape are subjected to the magnetic field produced by a recorded signal on an adjacent layer. It is a nonlinear process, without bias, and the effect is particularly related to nonuniformity of magnetic characteristics of the oxide particles; usually it will be most severe with the so-called "high-output" oxides. The degree of initial print-through, assuming all other conditions to be equal, is some exponential function of the recorded signal strength. Exposure of the layer-upon-layer recorded tape to a weak a-c field has a linearizing effect on the unmagnetized layer, thereby causing layer-to-layer recording to take place. If the a-c field is very strong, the recorded signals will be completely erased. A field strength of 500 oersteds or more normally is used in practice to "bulkerase" tape. Such high-intensity fields would probably not be encountered accidentally; however, weak fields of sufficient intensity to increase print-through effects can conceivably exist. Such fields (an example, power transformers) should not be close to the magnetic-tape-storage area.

The application of *heat* has an effect similar to weak a-c fields in that it increases the magnitude of print-through, but to a smaller degree. There is some disagreement about the effect of time on print-through, but it is generally agreed that the change of temperature during the storage period is more of a contributing factor in print-through than time, per se.

Storage

Other contributing factors which can affect the medium of magnetic tape from the standpoint of the permanency of storage of information are *dust* and *position* of the reel in storage. Tapes should be stored in a container or area which is free from dust, with the reel flanges in a vertical plane, and the reels should be supported by the hubs.

The medium of magnetic tape can justly be classified as a permanent means of storage if (a) proper storage requirements are met and maintained, (b) proper techniques are exercised in the handling of the tapes, and (c) the tapes are not continuously put to use but rather serve only as a master record from which to reproduce other tapes for working functions with computer systems.

Photographic Systems

Photographic methods have been considered by many to contain excellent potentialities for providing good means of storing enormous amounts of data for an indefinite period of time. Considerable work is now being done in this field by several different establishments. Results of these efforts are beginning to show in the forms of operating systems producing results. Some of these systems are:

1. **The rapid selector:** There are two experimental models; one being developed by Engineering Research Associates, one being developed by Yale University at the National Bureau of Standards.
2. **The Minicard system:** A system being developed by the Eastman Kodak Company.
3. **The photoscopic information storage unit:** A system which permits information to be stored at a density of a million bits per square millimeter

is being developed by the International Telemeter Corporation.

4. **The FOSDIC filmer:** A system which was developed by the U.S. Weather Bureau of the United States Department of Commerce and is now being used by them.

Although most photographic methods are still in an experimental stage, some are in use. One of these which looks quite promising is the FOSDIC system (*Film Optical Sensing Device for Input to Computers*). This system is now being used. This system consists of the FOSDIC Filmer (a unit which places 13,000 card images on a 100-ft reel of 16-mm film), and an electronic film scanner (FOSDIC) which searches the film data content at the rate of 4,300 card images per minute, and copies out the selected card images to an IBM card-punching machine. Future models of FOSDIC could operate at least four times as fast, and will be able to read directly into computers or into magnetic-tape-recording stations preparatory to computer processing.

Microfilm has several advantages over the other known data media. Some of these are safe durable recording, compact storage, and economy. Microfilm data can be altered only by physical destruction or loss of the medium. Data on magnetic tape can be erased, garbled, or written over. Individual punched cards can be lost or altered. In the punched-card microfilm of the FOSDIC system, the data density is 860 characters per inch of 16-mm film; this density is several times more compact than for magnetic tape; the storage space advantage over punched cards is 180:1, and over paper tape about 100:1.

Photographic methods for permanent storage of data are still in their experimental stages, and they are not readily available on the commercial market. They look quite promising, however, and could afford an excellent means of implementing a permanent storage record center.

Other Media

Other media which are available for storage of information for use with automatic computers are *magnetic discs* and *data files* (strips of magnetic tapes).

Two other methods of storage which look promising, but are still in the development stage, are the *Magnacard* system (being developed by the Magnavox Corporation) and an *optical disc storage system* (being developed by the International Telemeter Corporation).

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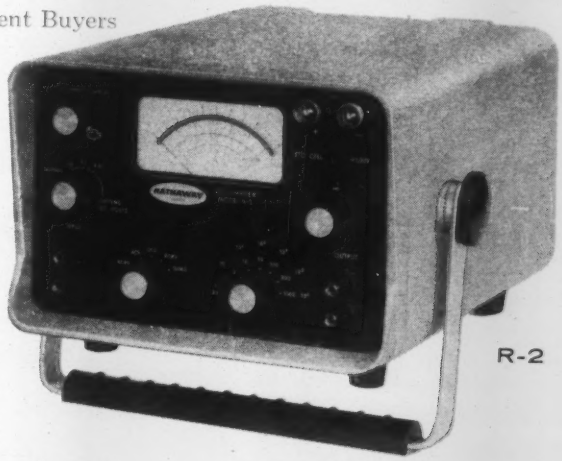

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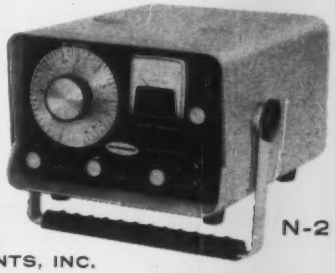

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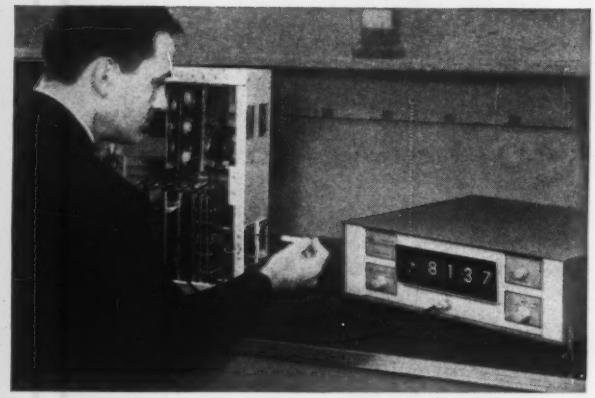

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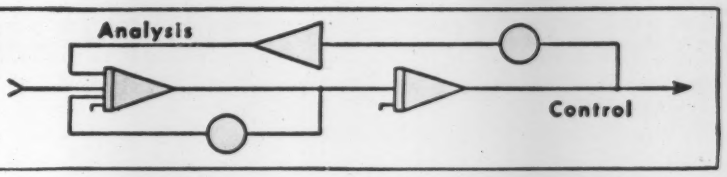

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Bits

This month we have accounts of:
Eastern Simulation Council—"Hybrid Computer Inter-Connection for Systems Simulation," 15 August 1960, Owego, New York.

"DDA Considerations in Combined Computation," R. J. Leake (IBM-Owego)

"The GE-MSVD Combined Analog—Digital Computer System," Martin Paskman (General Electric, Philadelphia) (Whole paper!)

"Some Insight into Time Scaling," Julius Port (Republic Aviation, Farmingdale)

Central Simulation Council—"Process Dynamics," 19 September 1960, St. Louis, Missouri.

"The Effects of Second-order Kinetics on Chemical Reactor Control," L. H. Fricke (Monsanto Chemical, St. Louis)

"Nonlinearities in the Mercury Capsule Heat Transfer Problem," M. S. Fineberg (McDonnell Aircraft, St. Louis)

"Nonlinear Simulation"—Panel Discussion

Also in the *Newsletter* this month we have "SCI Activities," with a few words on material received and programs announced.

No Info, no thots!

Pieces

EASTERN S/C MEETING OF 15 AUG. ON HYBRID SYSTEMS

The Eastern Simulation Council held a meeting at Federal Systems Division of International Business Machines Corporation in Owego, New York on 15 August 1960. The subject for the meeting was "Hybrid Computer Inter-Connection for Systems Simulation."

Leake on DDA Considerations

The first presentation, by *R. J. Leake* (IBM-Owego), was "DDA Considerations in Combined Computation" and was concerned with certain aspects of the integration of a Digital Differential Analyzer into a Simulation Facility for the purpose of combined computation.

Mr. Leake described experience gained in the inter-connection of a laboratory model DDA into IBM-Owego's new Simulation Facility. The facility is still in the final stage of completion, so no problems other than those of a routine checkout nature have been run.

Mr. Leake spoke of some of the speed-accuracy relationships of the DDA. Incremental computers, he explained, can be classified as digital computers in which all information transfers are in the form of differences which are smaller than the standard machine word size. The logical structure of these machines is usually such that a particular difference equation is solved in an efficient repetitive manner, and all arithmetic operations are performed by using adaptations of the specialized machine difference equation to yield approximate numerical solutions.

Because DDA machine variables are based on incremental rather than whole word changes, the rate at which they can change is somewhat limited, with the result that the DDA has been considered prohibitively slow for real-time simulation purposes. However, Mr. Leake's point of view was that DDA's are too slow only for a restricted class of problems. A broad class of control problems with relatively slow response times lend themselves readily to DDA simulation in real time.

Stating that the nature of the machine speed limitations become obvious to the programmer who gains familiarity with the scaling relationships involved, Mr. Leake considered a simple sine-wave generator program and derived the equation

$$f = Q/(2^N)(2\pi), \text{ cycles/sec}$$

which gives the rate at which a binary DDA of Q iterations/second will generate a sine wave if the dependent variable register is N binary digits in length.

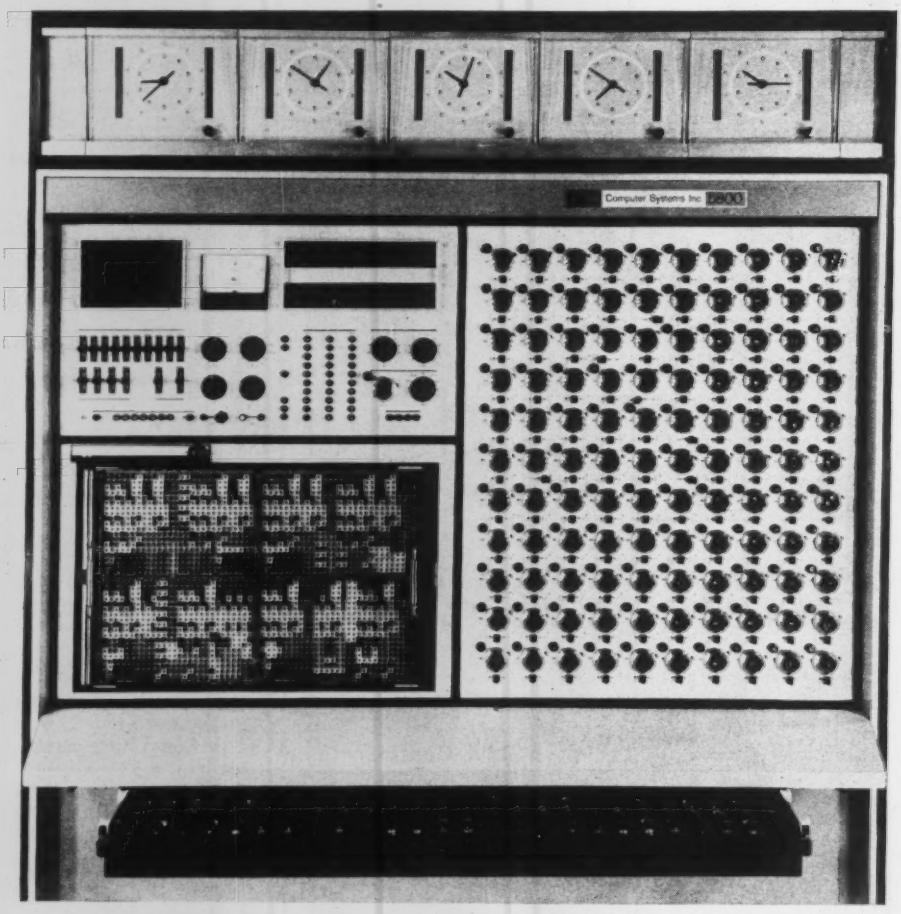
Fourier integrals with parameter variations

$$A(u)\ \text{real} = 2\int_0^1 f(x)\left[\cos\left[(\psi(x)+ux)\right]+\cos\left[(\psi(x)-ux)\right]\right]dx$$

solved in 60 seconds...

$$A(u)\ \text{imaginary} = 2j\int_0^1 f(x)\left[\sin\left[(\psi(x)+ux)\right]+\sin\left[\psi(x)-ux\right]dx\right]$$

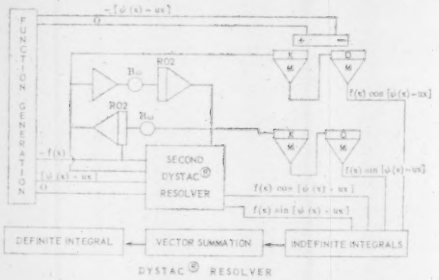
with DYSTAC® 5800 Analog Computer



Chemical process evaluation, microwave antenna design, aircraft and missile design...these are but a few of the parametric studies that DYSTAC, and only DYSTAC, can perform. DYSTAC 5800 is the only analog computer with a memory and high-speed repetitive operations. These two unique capabilities allow the 5800 to make rapid solutions to problems that would otherwise require error-producing over-simplifications.

Unlike other analog equipment, the DYSTAC 5800 utilizes time-sharing of components, thus greatly decreasing the size and cost of the computer relative to its capability. The high-speed rep-ops, together with dynamic storage of analog data, give the machine the best features of analog *and* digital computation. It is the only computer capable of solving equations with two or more independent variables in 60 seconds or less. In addition, it assures data storage accuracies of 0.01% and a time-base accuracy of ± 0.5 μsec.

Send for our 11-page report, "Solutions to Bounded Fourier Integrals on the DYSTAC Computer."



COMPUTER SYSTEMS, INC., Culver Road, Monmouth Junction, N. J. • DAvis 9-2351

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CIRCLE 65 ON READER-SERVICE CARD

RICHARD J. LEAKE, now with IBM Corporation, Owego, New York, has a BSEE from Carnegie Institute of Technology, and has performed graduate work at Rutgers University and Syracuse University. He is engaged in logical design of airborne digital computers, and analog-digital simulation, with special interests in incremental computation.

However, he cautioned his listeners against mistaking the quantization level as a true indication of accuracy because the machine accuracy depends on the numerical process taking place, and certainly more than roundoff error must be considered.

Mr. Leake next took up another figure of merit, the rate at which a machine can slew to a particular variable size, and showed that the slewing time is given by:

$$T_1 \cong 2^N/Q, \text{ sec}$$

The quantization level is one part in 2^N so, in a pratical case, if $Q = 1{,}000$ iterations/sec, and $N = 10$,

$$T_1 = 2^{10}/1000 = 1 \text{ sec.}$$

Thus it was shown that DDA slew time, at analog-computer accuracy, is almost comparable to typical analog-computer servo units, which may have slewing times up to several tenths of a second.

Mr. Leake then made an estimate of the frequency domain characteristics of the DDA by considering the generation of an isosceles triangle formed by first slewing to some peak value and then returning to zero at the same maximum slew rate; then, neglecting quantization "noise," making a spectral analysis.

From this he concluded that a relatively low-grade filter or data reconstruction device can be used to recover the continuous solution in the time domain. This is almost intuitively obvious, however, as we know that variables within the DDA do not vary at high time rates, and it follows that the high sampling rate (i.e., iteration rate) is more than sufficient to handle the information content of frequencies generated by the machine. For these reasons it is convenient and adequate to consider only the solution envelopes, and we can thus consider from a restricted systems standpoint that the DDA performs as a low-speed analog computer whose outputs are available in sampled digital form.

Except in cases of trivial problems, accurate solution-time estimates can be made only by scaling the particular program in mind. When this is done it will (hopefully) be possible to isolate an independent variable which "drives" the problems. An accurate time estimate usually can be made from (1) the scale factor of the independent variable, (2) the number of units of the independent variable for which a solution is desired, and (3) the basic iteration rate. If it is desired to speed up the problem, the word length of all variables can be shortened with a corresponding accuracy loss.

Mr. Leake noted from the example on slew-speed determination that there is a definite upper limit on the rate at which a variable can change within an incremental computer. The systems constraint due to this limitation is that great care must be taken to determine the rate of change of certain real-time inputs to the computer.

Having established certain relationships between machine speed and word length, and mentioned some input-output and control considerations, the speaker concluded that the speed capability of incremental computers depends on the basic machine iteration rate and the scaling of the program; for each additional level of quantization the time required for solution will double, and it is approximately true that for each additional decimal place of accuracy the time required for solution will increase by a factor of ten. For these reasons it will not generally be feasible to expect extremely high accuracies when using the DDA for combined computation.

Refined integration schemes and large increment transfers can increase machine accuracy, so that word lengths may be shortened and a corresponding increased speed realization is possible.

Due to the wide variety of possible program configurations, no definite statements regarding the DDA frequency domain limitations can be made. Whether or not rate limiting is necessary for real-time inputs depends on the situation. In many cases the frequency spectrum of the input signals can be quite broad, even extending to about one fifth of the sampling frequency (iteration rate). The transfer function of DDA programs, however, almost invariably will take on the nature of a low-pass filter so that the output spectrum will consist primarily of low frequencies.

However, it should be mentioned that DDA's can handle problems up to full integrator capacity with no additional penalty in solution time. This is an important factor when compared to the general-purpose digital computer. The GP solution rates depend entirely on the amount of computation to be performed. In any case, if the details of the operation methods to be employed are left to the programmer, the effectiveness of the speed-accuracy compromise depends to a great extent upon the skill of the programmer in the fields of numerical analysis and logical manipulation, and the time allowed for program preparation.

By taking specific examples and comparing solution times of a 73-integrator DDA having an iteration rate of 623 iterations/sec with the IBM 704, the following generalizations were made:

a. For problems requiring 3 to 5 decimal places of accuracy and demanding full integrator capacity of the DDA, the incremental computer has a definite speed advantage. This advantage is further enhanced by the fact that the DDA can readout "on line" (i.e., there is no need to hold up computation processes while reading out results).
b. Problems requiring greater than 7 decimal places of accuracy, and not large enough to demand full DDA integrator capacity, are more rapidly solved on the general-purpose computer.

Mr. Leake explained that unfortunately no specific statements can be made regarding the vast "gray" areas which are not included in the above generalizations; too much depends on the nature of the individual problem.

The ease of programming the DDA is a definite factor when deciding which type of digital computer to use for the solution of differential equations. Another important con-

sideration is that convergence problems are not nearly as critical with the DDA due to the extremely simple integration processes involved. In addition to the above factors, the incremental computer updates all solutions at a high rate, making it desirable in certain control loops involving analog equipment.

Mr. Leake explained that the advantages pointed out are not intended to imply that the DDA has in any sense more over-all utility than analog or general-purpose digital computers, but rather that it is a desirable partner in combined computation. Combined computation implies that the problems being solved are so large or complex in nature that they cannot be handled readily on a single computer. Since general-purpose digital computers require solution times proportional to the size of the problem, the speaker pointed out that if it is possible to allocate portions of the computation to a DDA, an over-all time saving should result.

From an external standpoint, DDA behavior is in many respects similar to a low-speed analog computer with sampled outputs. With this in mind, many general-purpose computer programming techniques developed for analog-digital computation can be applied to the GP-DDA combination. Furthermore, this likeness enables the DDA to aid in analog-computer computations. Three promising applications of the DDA in conjunction with analog computers are (1) nonlinear function generation, (2) the performance of multiplication operations, and (3) simulation of sampled data systems.

* * *

There has of late been such an upsurge of interest in the subject covered by the next paper that we pass it on to you here almost as we received it.

GE-MSVD COMBINED ANALOG-DIGITAL COMPUTER SYSTEM

Martin Paskman, General Electric, Missile and Space Vehicle Dept., Phila. 1, Pa.

MARTIN PASKMAN was born in 1928 in Philadelphia. During World War II he served in the U. S. Navy as an Aviation Radioman, Combat Aircrew. Following active service during the Korean War, he received his A. B. degree in 1953 from U. of Chicago. He joined the Martin Company in 1956, where he worked in the Analog Computer Laboratory as a programmer. In 1957 he joined Aircraft Armaments, Inc., as engineer and consultant on computers. He joined General Electric Company as a specialist in Dynamic Analysis. At General Electric Company, Missile and Space Vehicle Department, his work in simulation led to the Development of the GE-MSVD Combined Analog Digital Computer System.

The development of the Combined Analog-Digital Computer System at GE-M&SVD was brought about by a management concerned with the necessity of being able to simulate, adequately and economically, complex systems. Consequently, early in 1958 an informal group was set up and an investigation into the feasibility of Combined Analog-Digital operation was instituted. This group carefully evaluated the capabilities and limitations of both Analog and Digital computers. They also tried to peek into the future to see what lines of development these existing systems would most probably follow. The characteristics of these two different computer systems are well known, so there is no need to enumerate them specifically. As to future development, it must be admitted as far as digital computers were concerned, the IBM 7090 was the horizon.

Analog computers, however, presented a different story. Here it was felt that the lines of development would concentrate on more automatic means of set-up and check-out—namely, digital input systems. This, also, was not so difficult to see with several manufacturers already placing on the market servo-set potentiometers and tape set-up devices. One other expected analog development which has not yet matured is the digitally set, automatic patching system. Thus, equipped with some idea of what to expect along each of the separate pathways, we could look at the development of combined systems.

During the previous few years the idea of linking together General-Purpose Analog and Digital Computers into one complementary system has seemingly gained momentum. Convair-Astronautics, Space Technology Laboratories, and the National Bureau of Standards, among others, had constructed such systems. Other systems were being proposed. These systems were studied carefully with the hope that they would be a good jumping-off place for the development of ours. Fortunately we found those groups cooperative, and they contributed much to our thinking. At that time there were three major questions which we set out to answer. These were:

1. What were the areas of major applications and was this coincident with our simulation requirements?
2. Was such a computer system feasible both technically and economically?
3. What were the general requirements for a useful combined Analog-Digital system?

These questions were closely interrelated and the requirements arrived at reflect this interdependence. These general requirements were:

1. VERSATILITY: The combined system should be capable of handling a large range of simulations without requiring special treatment or major modifications.
2. UNITY: The Combined Analog-Digital computer should be so well integrated that during operation it behaves essentially as one computer. This concept applies also to unity of control of operation.
3. ACCURACY: Problem solutions should have repeatability to within given and predictable ranges.
4. RELIABILITY: Over-all equipment reliability should result in minimum down time.
5. EASE OF PROGRAM MODIFICATION without extensive tie-up of equipment.

6. SUBSTITUTION OF HARDWARE COMPONENTS, analog and digital. Thus real-time simulation can be accomplished using a wide variety of system hardware.

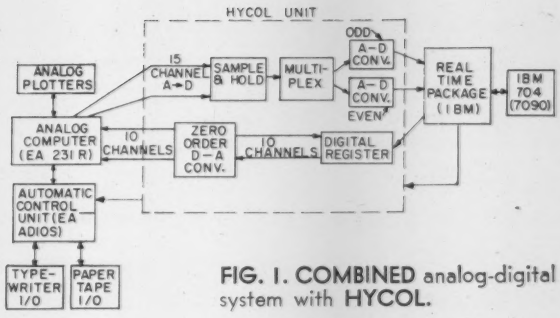


FIG. 1. COMBINED analog-digital system with **HYCOL.**

The achievement of these system requirements did not necessarily have to be obtained by hardware design alone, but they did have to be inherited in the logic of the Combined Analog-Digital Computer System. The GE-MSVD HYCOL (*H*ybrid *C*omputer *L*ink) is the direct outgrowth of these requirements. HYCOL itself is a means of linking together a high-speed general-purpose Digital Computer with an Analog Computer for simultaneous operation.

The discerning reader will have noticed by this time that I have begged the first two questions and have detailed the third. This has been done, not with intent to defraud, but because I feel that they can be better answered with some knowledge of the system acquired first.

II. OPERATION

The present IBM 704 installation is located on the fifth floor, and approximately 300′ of cable run connects it to the sixth floor Analog-Computer installation. Located next to the IBM 704 is a cathode-follower compatability unit which adjusts pulse heights to and from the Digital Computer. The HYCOL system itself is located on the sixth floor next to the Analog Computer. Thus only digital information is transmitted over long distances.

Figure 1 shows a generalized block diagram of the combined Analog-Digital system. The Analog computer portion of the system consists of an Electronic Associates 231 R Analog computer with the Automatic Digital Input Output System (ADIOS). In addition to the typewriter and paper tape I/O devices, 6- and 8-channel curvilinear and rectilinear records are available, as well as X-Y plotters and a 30″ x 30″ dual-arm X-Y recorder.

The 15 channels of Analog-to-Digital conversion information are sampled by a simultaneous "Sample and Hold" circuit; the information is then multiplexed through two A→D converters. The cycling time of the converters is 72 μsec. However, by alternating between two converters, an effective 36 μsec conversion rate is accomplished, except for the initial access. The information then flows sequentially into the Digital Computer, where it is acted upon.

Information flowing from the digital computer, sequentially, is held in 10 digital registers. When it receives the convert signal, the digital information flows simultaneously out of the digital registers through a Packard-Bell zero-order converter into the Analog Computer.

Up to this point the Missile and Space Vehicle Department system shows no radical departure from other built or proposed linkage systems. Nor does the HYCOL hardware, taken individually, present any real accomplishment, on our part, in advancing the "state of the art." However, it is at this point that the Missile and Space Vehicle Department system differs radically from any other known to us.

In approaching the design of HYCOL we tried to determine which features of the Analog and Digital Computers were complementary, and how these complementary features could be utilized best. The logical nature of the Digital Computer allows it to have a large latitude in decision-making; consequently it was decided to assign control function responsibility to the digital computer. The *specific* control functions assigned are:

1. **Analog Computer start, stop and hold.**
2. **Analog-to-Digital and Digital-to-Analog Conversion within the HYCOL.**
3. **Control the time generator (clock frequency).**
4. **Control sequencing and order of sampling of the multiplexer for Analog-to-Digital conversion.**
5. **Act as an input device for the Analog Computer automatic-control device (EA ADIOS system). Consequently, it is capable of setting up pots and function generators as required.**

The implication of this design philosophy can best be seen by considering the steps for a typical problem. First, the Analog Computer is patched independently of the Digital-Computer program. At the start of the combined operation program the input information is fed into the Digital Computer from cards or tape. The Digital Computer then will run through a diagnostic routine which will check out the operation of the HYCOL unit and the passage of information and control signals through the HYCOL, ADIOS and Analog-Computer system. Upon completion of the diagnostic routine, if trouble occurs, the Digital Computer will print out, on line, the checks and where trouble has occurred. The Digital Computer then can be instructed manually whether to continue or to return to other work and dump the present problem on to tape or other storage media. On the other hand, if everything checks out within the specified areas, the computer will go on to the next stage.

In the second stage, the computer can calculate potentiometer settings, if desired, and then it will instruct the ADIOS System to begin setting the pots. As each pot is set the original instruction set from the Digital Computer is printed out and the potentiometer read-out is also printed. Provision can be made to return the data to the Digital Computer for comparison with the original pot-set instruction to see if an error has occurred. Servoset diode function-generators also can be set in this manner. If an error occurs, the Digital Computer then can send back, for a second or any other number of times, a pot-set instruction to see if it will work. At the completion of this stage, if no error exists, it will go on to the

next stage; if an error exists, it will print out the failure and wait for further instructions as before.

For those familiar with the difficulties involved with the simulation of large problems on the Analog Computer, I am sure this next step is one they will appreciate. Static checks on the Analog Computer are generally made by substituting fixed values for the variables into the original mathematical equations, and then solving for the steps involved in the analog mechanization. The values of operations that take place (in the form of scaled voltage read outs) then can be compared with the arithmetical solutions to determine if the components are operating correctly, or if a mistake has been made in the mechanization. This is done with the computer in the pot-set or static mode, and corresponds to $t = 0$. This does *not* check the dynamics of problem solution. During the static check step in our combined analog-digital operation, the computer can substitute this fixed value into the original equations, then, through the ADIOS unit, place these calculated values in the Analog Computer. It then proceeds to a "read-out" mode and compares the read-out values with the calculated values. If there is an error during the static check cycle, the machine will complete all the checks and then printout the results. If no error occurs it will then proceed to the actual problem solution calculations.

Upon completion of the problem solution the Digital Computer can commence a problem evaluation sequence or, if a parametric study, the parameters can be varied in some predetermined manner; a complete parametric study of a navigation intercept could be made in about 2 hours of running time on the 704.

One additional item to be pointed out is that of data output. Using such a system as this, one has three means of data output:

1. Analog output while the problem is running.
2. Digital storage and then print-out on line after each sequence of events.
3. Digital storage on tape and print-out off line.

For most applications it will be found that a mixture of all three of the above will be used.

III. APPLICATION

Before discussing actual application of a combined Analog-Digital computer, I should like first to attempt to classify the types of problems done in engineering analysis into general areas, and also to define a few terms in common use. These general areas are:

1. COMPUTATION: These are operations which involve arithmetical manipulation. Matrix inversion, some areas of operations research, or just plain filing can be classified under computation.
2. SIMULATION: Here we place all those operations which involve the construction of analogs of the system or subsystem being analyzed. There are, in general, two major sub-classes of simulation: Mathematical and Physical.
   MATHEMATICAL SIMULATION involves the construction of the analog in accordance with a mathematical model of the system or subsystem.
   PHYSICAL SIMULATION in general tries to create, under laboratory control, operating conditions which the actual system or sub-system might meet during the performance of its mission. The substitution of hardware components for their mathematical counterparts in a system simulation also is considered physical simulation.

The general terms are:

1. RESOLUTION: The capability of distinguishing small differences between large quantities or the difference between a large and a small quantity.
2. PRECISION: The capability of describing a quantity to a large number of places.
3. ACCURACY: The capability of solving a problem or simulating a system to within a given or known error or area of uncertainty.

The combined Analog-Digital computing system will find its major areas of application in simulation. It is in this area that the complementary features of each machine can be utilized to the fullest extent. For the purpose of illustration let us consider briefly a simulation proposed for combined Analog-Digital simulation—the dynamics of missile motion. For this example let us choose a 3-degree-of-freedom planar study of a controlled vehicle.

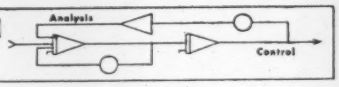
The major problem which arises in any combined Analog-Digital simulation is that of determining what is to be solved for in the Analog computer and what is to be solved digitally. To make these decisions effectively several questions first must be resolved concerning the system to be simulated. These questions are based on the definitions of the general terms "precision," "accuracy," and "resolution," which we just defined.

Looking at the equations of motion of the system, we can ask and answer some of these questions. For instance, forces are being summed, and these forces can be both large and small, sometimes ranging as high as several magnitudes in differences. The digital machine presents itself as the natural place to sum these forces to get the necessary resolution. In the digital we can maintain resolution to as many places as we require. We also find that if we are talking in terms of generating functions of two or more variables, this can be done most precisely in the digital, either through table look-up or polynomial approximation. Another criterion would be that of resolution determined from the required analog scaling. Generally we know our aerodynamic functions fairly well to orders-of-magnitude relationships, but the accuracy to which they can be determined is rather poor, perhaps on the order of 10 or 20 percent. Consequently, if our dynamics can be generated to one or more orders of magnitude better, then we have adequately simulated the system. At this point we can justify integrating our dynamics on the Analog Computer and thus take advantage of one of the unique capabilities of the Analog. These same criteria then can be applied to the rest of the system.

There is, however, one unique problem in dealing with combined systems that one does not have with Analog systems (but can be found with closed-loop digital systems)—this is the problem of *truncation* and *transport delay*.

Truncation is due to the sampling interval and corresponds to truncation in numerical integration. The error due to truncation can be limited, because the combined system has a high sampling rate and the "time" of problem solution can be slowed down (for non-hardware problems), allowing the interval to become as small as desired. Other digital techniques can also be applied to limit or even eliminate the effects of truncation.

Transport delay has the effect of putting a first-order lag into the system. The effect of transport delay is cumulative. This problem arises because a finite amount of time is taken to sample, operate on and return the data to the Analog. This interval is known, so in most cases the effects can be minimized or entirely



eliminated by an error function utilizing the derivative. One can also take advantage of this lag by including it as part of the time constant in the simulation.

In most cases it would be best to put the complete control system on the Analog Computer, thus making possible rapid changes of the control configuration. Of course, if a Digital Computer is part of such a control loop, this would be handled in the digital portion of the simulation.

This is one type of problem suitable for combined computer simulation. Another area of promise for this type of system, which takes advantage of its unique capabilities, is the solution of systems of partial differential equations by utilizing Monte Carlo techniques. This could be accomplished in conjunction with a repetitive-type Analog Computer and by discretizing time.

IV. FUTURE DEVELOPMENTS

The Combined Analog-Digital System may be the first step in the eventual development of a new kind of systems simulator. A few words should be said about those developments which are on the immediate horizon.

In the near future, we expect that *automatic patching* will be incorporated to some extent into the system. Along with the development of automatic patching will be what Lee Ohlinger on the West Coast calls ANATRAN. Anatran or *Anal*og *Trans*lator is a "compiler" similar to FORTRAN, which will essentially program the analog computer on the digital. Such translators have been worked on by several companies already; among them is Martin-Baltimore.

Once embarked on ANATRAN, then comes HYCOTRAN or *Hy*brid *Co*mputer *Trans*lator, which will essentially do the same thing for hybrid programming. This, in conjunction with Automatic Patching, should make hybrid operation more or less completely automatic. Digital diagnostic routines then can be prepared for check-out of a complete computer system both dynamically and statically, making diagnosis of hybrid and analog-system illnesses both rapid and economical. Problem check-out also can then be made both statically and dynamically.

Now, like a bad guest, I shall criticize our host (IBM) along with the other computer manufacturers. Today's digital and analog computers are not flexible enough to do the complex systems simulations required for missile and space vehicle systems developments, nor are they economical. For instance, the single-operation console-patchbay analog computer ties up all the elements of a console regardless of size of problem. Therefore, a problem of ten amplifiers is just as costly to run and ties up nearly as many elements as a hundred-amplifier problem.

The same is true for the digital computer; here one of the major sources of cost is in packaged hardware sub-routines or instructions which we pay for even if we do not require them all the time. Other problems also arise in utilizing the digital computer for systems simulation. For instance, in the generation of functions of two or more variables, hundreds of machine cycles and large amounts of storage are required for table look-up and interpolation of just one function. Multiply this by the number of functions required for just the rigid-body equations of motion, and you can see that a major portion of computer time is spent in just function generation. On top of this, imagine trying to simulate the DDA portion of a digital-DDA inertial-guidance system such as are in common use today!

The method of obviating this problem has been suggested by several sources. Ramo-Wooldridge, Intellectronics Division, has applied the word "Polymorphic" to their modular-type computer, and I would like to extend the concept even further to a truly "Polymorphic" Combined Analog-Digital Systems Simulator (CADSS). The first steps towards such a system already have been taken by the National Bureau of Standards with their PILOT computer system. PILOT consists of three separate computers, one of which acts as a control unit and one an arithmetic unit, while the third controls input-output from tapes, analog-to-digital and digital-to-analog devices and other devices. The PILOT system is expected to give speeds of 10 to 100 times greater than presently operative computers.

The system which we have in mind is even more general and flexible than the Pilot system. Basically, the system consists of storage elements (digital), arithmetic and logic elements, a central control console, and HYCOL. The general-purpose IBM 7090 can be included as an element of the system as well as the general-purpose analog computer. Provision is also made for the inclusion of Real Time and Direct Analog devices.

The storage element can be composed of cores, tapes, or even character-recognition devices, and is expandable modularly, as are all other elements in the system. They are at all times under the control of the Central Control Console, and can be switched as required for problem solution.

The basic elements of a computer system are gates and flip-flops; consequently the digital arithmetic and logic units are such packages. Their configuration, and consequently subroutines, is under the control of the Central Control Console, although it is possible that some of the elements might be "pre-wired" to form registers, multipliers, etc. since these are devices which are constantly in use.

The *Central Control Console* is the heart of the computer system. It acts essentially as a traffic-control policeman, routing traffic through the system. Basically, it consists of electronic and mechanical switching matrices which are under the control of the stored program (or programs). In this manner it can control the flow of information and the operations on that information.

Analog elements also would be under "control" of a digital program, and consequently no patchboard or console-type operation would be required. The analog elements would be assigned to a problem mechanization as required, either pure analog or combined with the other elements.

Because of the flexibility inherent in programming for the system, all the elements of the system could be applied to the solution of a very large problem, or "time shared" for the simultaneous solution of smaller problems.

Taking a large problem we can quickly examine how the system would operate, say for function generation. In this case the "main" program would be in the large-scale general-purpose digital computer. It would ask the central control console for the specific functions of several variables. The central control console would set up the configuration for generating these functions. By utilizing table look-ups in parallel from the storage, and interpolating in parallel by the digital arithmetic and logic units, the functions could be generated and presented to the GP

JULIUS PORT is now with the Scientific Research Staff of Republic Aviation. For 5 years Mr. Port was assistant supervisor of the analog computing group at Republic. He has designed computing systems for Curtiss-Wright simulators, and taught physics and mathematics for Newark College of Engineering. He is presently teaching analog computing for Polytechnic Institute of Brooklyn. He has a master degree in mathematics (1948) from New York University.

digital computer. During this time the GP digital computer would be acting continuously on other parts of the program, the information arriving as required. Extending this, we can see how part of these elements can act as a DDA while perhaps a portion of the control system and the dynamics are being simulated by the analog elements.

Programming such a system will be a real job of ingenuity. However, experience will build up programmed sub-routines which can eventually be utilized for a "Fortran" type system. Although we here in the U. S. like our "packaged" program instructions, it must be pointed out that the Europeans and Russians have utilized effectively, for the solution of complex problems, computer systems with only a limited number of packaged sub-routines. Consequently they have kept the price of these machines economical and, in fact, prefer programmed sub-routines rather than hardware.

Little imagination is required to see what one would be able to do with such a computer system, if it existed. Unfortunately it does not exist today. But I believe that the requirements for complex systems simulation, not only in the space industry but in process control and many others, is such that a few years hence will see variations of such systems.

* * *

Port on Time Scaling

The third presentation on the program, "Some Insight into Time Scaling," by **Julius Port** (Republic Aviation Corp., Farmingdale, New York), was tutorial in nature. The importance of the subject cannot be questioned, but it has received so much attention elsewhere that it will not be re-presented here. Nevertheless, some of Mr. Port's closing comments are worth noting:

"The occasional confusion between machine time and problem time is merely the result of bad notation.

"If λ is varied by using ganged potentiometers before each integrator, instant by instant, the correct relation is maintained among the dependent variables. If an X-Y plotter is used to record one variable against another, the pen will trace the same path whether λ is fixed or is changed at random during the run. If the sign of λ is changed the direction of pen travel along the path reverses, but the path remains unchanged. Thus, it is always possible to program a problem in such a manner that there is no coupling between time and voltage scaling.

"A computing-machine result is meaningless unless interpreted by scaling. Whether treated explicitly or not, scaling equations must exist which transform the input-output relation of every individual operation of the machine to either a problem-determined equation or a redundancy. There are no exceptions to this.

"It should be noted, however, that machine operations are almost never the exact analog of what is needed for a problem solution. Approximations must be made both in writing the problem equations and in describing the machine operations before it will be possible for the scaling equations to transform the machine operations into the problem equations."

CENTRAL S/C MEETING OF 19 SEPT. ON PROCESS DYNAMICS

We are indebted to **Verlin A. Lauher** of Monsanto Chemical Co., St. Louis, for a letter report that was so well done that we give you his words here almost verbatim:

The Central Simulation Council meeting on "Process Dynamics" was held at Monsanto Chemical Company in St. Louis, Missouri, on 19 September 1960. Mr. **L. H. Fricke** (Monsanto Chemical Company) presented a paper on "The Effects of Second-Order Kinetics on Chemical Reactor Control." Mr. Fricke pointed out the possibilities of "false start phenomena" present with certain control systems. The reasons for incorrect conventional control and methods of correcting these errors were discussed. A digest of the paper (prepared by Mr. Fricke) follows:

Fricke on Reactor Control Kinetics

When the reactions taking place in a chemical reactor system can be characterized as a set of simultaneous second-order differential equations, the reaction presents some interesting complex problems for the engineer concerned with its control. Because of the kinetic interactions of the reactants, intermediates and products, the reactor dynamics are complex and nonlinear in behavior. This paper explores the dynamics and control of one of the simpler chemical reactor systems which exhibits some of the typical problems of these systems. This investigation was done utilizing an analog computer.

The following are the basic assumptions used in this analysis:

1. Perfect first-order mixing occurs to the reactor contents.
2. The reaction occurs isothermally.
3. The densities of all streams are considered constant and equal.

The nonlinear properties of the reaction make it difficult to control the composition of the contents of the reactor in the conventional manner. This effect is most easily realized by referring to a plot of steady-state or static solution-composition contours for different reactant input flow ratios *versus* the residence time. If one were to operate a reactor with one input reactant flow rate fixed, then a locus of operation can be generated for flow ratios *versus* residence time (different volumes). Thus, if you

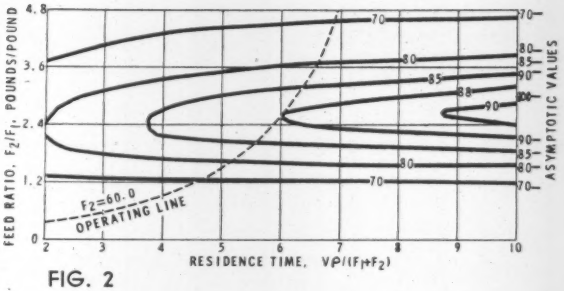


FIG. 2

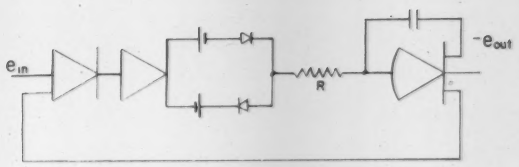


FIG. 4

CASES \ CONTROL		F_2	F_3	F_2 & F_3
#I	$\Delta F_1>0$	NO	No	YES
	$\Delta F_1<0$	YES	NO	Yes
#II	$\Delta F_1>0$	Yes	YES	YES
	$\Delta F_1<0$	YES	NO	YES
#III	$\Delta F_1>0$	NO	NO	YES
	$\Delta F_1<0$	Yes	NO	YES

FIG. 3

were not at the peak of the contour, it is possible for two identical composition valued steady-state solutions to exist at different flow ratios. Therefore, a conventional controller might resolve to either solution and/or be unstable in the region between. This is shown in Figure 2.

Three possibilities of control arrangements are presented. These are:

1. Control of one inlet stream by a change in the composition of the product in the reactor outlet flow (conventional).
2. Control of the outlet flow by a change in the composition of the product in the reactor (residence time control).
3. Control of one inlet stream by a change in the reactant inlet stream and control of the outlet flow by a change in the composition of the product in the reactor. This controls in an ordinate direction and an abscissa direction on Figure 2.

The above three arrangements were examined for three disturbance cases. These are:

1. Compositions initially at peak of the steady-state contour. Positive or negative changes in one outlet flow both cause a decrease in the product concentration in the outlet, the step changes in the inlet being in this case 50%.
2. Compositions initially above in flow ratio the peak steady-state contour. Positive or negative changes in the one inlet flow giving a "false start"; that is, the composition changes of the product experience a sign change for either inlet flow change. In this case, the inlet change was 25%.
3. Compositions initially as in 2. Effect essentially the same as in 2, but the "false start" is preceded by a true beginning. In this case, the inlet flow change was 50%.

The results of this study are summarized in Figure 3. The three possible control arrangements are listed across the table, and the disturbance cases are listed in the left column. The statement "yes" means the system returned to a predescribed setpoint while "no" means the control was completely lost.

This paper makes the following conclusions:

1. An analysis of the dynamics and control of a reaction system, where a second-order chemical reaction is carried out in a stirred tank reactor, has been made with the aid of an analog computer.
2. The dynamics of the reaction system exhibits "false start" phenomenon, which confuses an improperly designed control loop.
3. The selection of a control system is specific for each reaction system.

The false-start phenomenon occurs because of the interaction of the residence time and kinetic rate terms. These are of opposite sign and the residence time term predominates at time zero. However, after a short time the kinetic term predominates and reverses the action.

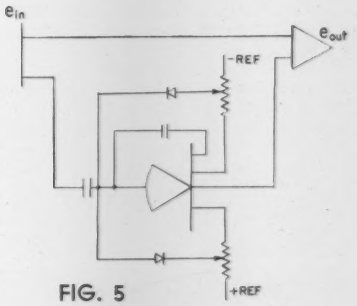


FIG. 5

Fineberg on Heat Transfer

Mr. **M. S. Fineberg** (McDonnell Aircraft Company), the speaker, next presented a paper on "Nonlinearities in the Mercury Capsule Heat Transfer Problem." Mr. Fineberg discussed the difficulties encountered in simulation of differences of two T^4 terms where T is the temperature of the member in question. Several methods of improved simulation over and above standard methods were presented. The best solution to the problem was obtained by the use of special diode function generators developing a fourth-power curve.

Figures 4 through 7 are self explanatory. They are methods of preparing special and periodic functions to be used as driving forces. Figure 8 is an improved method of computing

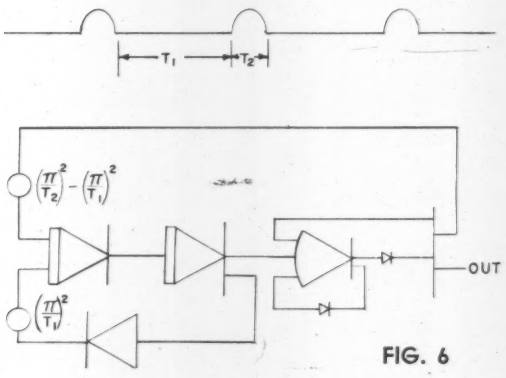


FIG. 6

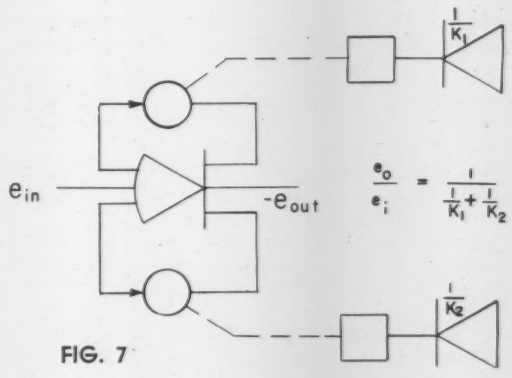


FIG. 7

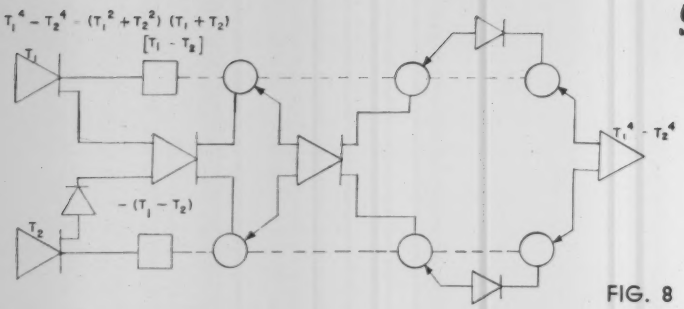


FIG. 8

the mutual radiation term encountered in the Mercury Capsule simulation. This method of simulation was successful but the fixed diode functions were considered far superior to the above method of computing mutual radiation.

Panel Discussion on Nonlinear Simulation

A lively panel discussion on the subject of "Nonlinear Simulation" followed the body of the meeting. Audience participation was high, under the able assistance of the panel members—**D. C. Augustin** (McDonnell Aircraft Company), **R. Dagenais** (Beech Aircraft Company), and panel director **P. E. Parisot** (Monsanto Chemical Company).

Resistine sheets used with X-Y plotters were discussed in detail. The conclusion was that such sheets are useful and hold their resistive distribution well if driven by amplifiers. The problem of servo errors around zero was discussed, and offset was considered the best method of correction. Fixed log function accuracy was discussed, and the conclusion was that the log function is accurate enough for most applications but lacking for certain special ones. It was also pointed out that the price of specially designed function generators may well be worth the expense if high accuracy is required.

MATERIAL RECEIVED TO BE REPORTED IN FUTURE *NEWSLETTERS:*

From **Maughan S. Mason** (Chairman, Rocky Mountain Simulation Council); a brief description of the 5 December meeting at White Sands Missile Range.

From **William F. Blodgett** (Chairman, Eastern Simulation Council); a complete report on the 12 December meeting at Computer Systems, Inc.

From **Martin Paskman,** General Chairman of the Simulation Councils Inc.—General Electric Combined Analog-Digital Computer Systems Symposium: the complete *Proceedings.* This meeting will not be covered in the *Newsletter* (except to say we have had many glowing reports not only concerning the technical presentations but also the arrangements and conduct of the whole affair). But the *Proceedings* will be available (courtesy of GE) from Simulation Councils Inc., 8484 La Jolla Shores Drive, La Jolla, California at $5.00 per copy.

PROGRAMS ANNOUNCED:

Western SC: meeting 12 January 1961 at System Development Corporation, Santa Monica, Calif., on
"Digital Simulation of Large-scale Man/Machine Systems" "Simulation as a Tool of Man-Machine System Research", L. T. Alexander
"Simulation as a Tool of Training", M. G. Holmen
"Role of Manned Simulation in Operations Research", W. A. Steger
"Effectiveness Studies of Manned Airborne Weapon Systems by Digital Simulation", P. H. Kennard
Introduction to tour of Q-7 (SAGE) Facility, S. Zasloff
Introduction to tour of Automated Teaching Project, H. F. Silberman
Introduction to tour of Experiment on Decision-Making in a Complex Environment", R. J. Meeker

Midwestern SC: meeting 16 January 1961 at Allison Division, General Motors Corp., Indianapolis, Indiana, on "Novel Solutions to Nasty Problems"
"Launching a Small Rocket from a Helical Rail", Joseph E. Wilson
"Analog Techniques Employed in a 'Half-way-round-the-world' Trajectory Study", R. O. Whitaker
"Simulation of Steam Generation in a Heat Exchanger", P. J. Hermann
"A Low-cost Time Delay", Ralph J. King
"Extended Use of a General-purpose Analog Computer for Missile Control System Development", J. E. Westwick

Southeastern SC: meeting 27 January 1961 at George Institute of Technology, Atlanta, Georgia,
"Moving Average" and a Report on Two Special-purpose Computers Designed for Medical Research

SIMULATION COUNCIL

SCI Activities

ROCKY MOUNTAIN S/C meeting: 24 June 1960 in Brigham City, Utah

Thanks to *Maughan Mason,* Chairman (Thiokol Chemical Corp., Brigham City, Utah) we have the following info on this meeting:

David R. Miller (President of Computronics, Inc., Denver 22, Colorado) described the Universal Non-linear Element (UNE) now undergoing development by his company. He discussed the theory and application, pointed out certain advantages and difficulties, and said it should be ready for production within three months.

Wayne R. Lym (Thiokol Chemical Corp., Brigham City, Utah) discussed ablative multi-material heat-transfer simulation using an analog computer. He indicated problem areas and described the checks made for accuracy. He also compared two methods of handling the ablation: (1) points equally spaced through the material, all points approaching each other during ablation; and (2) points fixed in the material with one "slab" at a time being discarded as the ablation progressed.

Only that—and nothing more!

MIDWESTERN S/C meeting: 8 August 1960 at Case Institute of Technology, Cleveland, Ohio, "Simulation in Systems Engineering"

Scheduled talks:

"The Systems Research Center at Case Institute" by **Donald P. Eckman** (Case Institute)

"Simulation of a Rubber* Processing System" by **Edward W. Snyder** (Goodyear Aircraft Corp., Akron, Ohio)

"The Role of Computers in the Engineering of Air Weapons Systems" by **Robert J. Harnett** and **A. C. Robinson** (Wright Air Development Division, WP-AFB, Ohio)

*This appeared in typed form first as a "Simulation of a Robber Processing System"—a truly intriguing problem!

"Digital Simulation of Engine Controls as a Part of a Jet Engine Propulsion System" by **Gerhard Reethof** (Engine Controls Analysis, Aircraft Gas Turbine Division, General Electric Co.)

"How the Analog Computer Serves Systems Engineering" by **William B. Field** (Systems and Control Analysis Section, Union Carbide Olefins Co., South Charleston, West Virginia)

We still hope *Bert Johnson*, the Midwestern Secretary, will give us the word on these presentations so we can pass them on to you.

EASTERN S/C meeting: 15 August 1960 at International Business Machines Corporation, Federal Systems Division, Owego, New York, "Hybrid Computer Interconnection for Systems Simulation"

Scheduled talks:

"DDA Study Group Summary Report," **W. McClintock** (Rensselaer Polytechnic Institute, Troy, N. Y.)

"DDA-GP Digital Interconnection for Simulation", by **C. Freitag** and **R. J. Leake** (IBM, Owego, N. Y.)

"G.E. Missile & Space Vehicle Department combined Analog and Digital Computing System" by **M. Paskman** (General Electric, MSVD, Philadelphia, Pa.)

"Some Insight into Time Scaling" by **J. Port** (Republic Aviation Corp., Farmingdale, Long Island, N. Y.)

In this case it is *William F. Blodgett*, the Eastern Simulation Council Secretary, that we hope to hear from concerning what was said.

WESTERN S/C meeting: 16 September 1960, at Edwards Air Force Base, Calif.

Scheduled talks:

"The Three-Axis Variable Stability Control Airplane—An Airborne Flight Simulator," **John L. Beilman** (Cornell Aero Labs, Buffalo 21, N. Y.)

"Project DATUM—Integrated Data Processing Facility" by **Fred Cox** (Air Force Flight Test Center, Edwards Air Force Base)

This time it is ye Ed who is on the spot because, although the Western Simulation Council always dutifully elects a Secretary, if I am able to attend a meeting I become ex-officio, willy-nilly, or somehow, expected to cover the meeting for the *Newsletter*. This time I goofed—my notes are nowhere near adequate.

However, I will try to recoup by writing the speakers for a summary of what they think they said.

CENTRAL S/C meeting: 19 September 1960 at Monsanto Chemical Company, St, Louis, Mo., on "Process Dynamics"

Scheduled talks:

"The Effects of Second-order Kinetics on Chemical Reactor Control" by **L. H. Fricke** (Monsanto Chemical Company)

"Nonlinearities in the Mercury Capsule Heat Transfer Problem" by **M. S. Fineberg** (McDonnell Aircraft Co., St. Louis, Mo.)

A panel discussion on "Nonlinear Simulation" by **D. C. Augustin** (McDonnell Aircraft Co., St. Louis), **R. Dagenais** (Beech Aircraft Co., Wichita, Kansas), **P. E. Parisot** (Monsanto Chemical Co., St. Louis) as Panel Director—and the audience

Verlin A. Lauher (Monsanto Chemical Co., St. Louis, Mo.) the new Secretary for the Central Simulation Council, already has reported on this meeting. So you'll probably get the story in your next *Newsletter*.

JOINT MEETING OF EASTERN AND MIDWESTERN S/C: 10 October 1960, at Union Carbide Olefins Company, South Charleston 3, W. Va. on "Simulation for the Process Industry"

We *certainly* hope to get the rundown on this one—from *Bert Johnson* (the Midwestern Secretary) or *Bill Blodgett*, then Secretary (now Chairman) of the Eastern Simulation Council, or *somebody*. We'll let you know.

"Simulation—An Aid to Process Control Design" by **Kenneth I. Mummé** (Kimberly-Clark Corp., Neenah, Wis.)

"Optimization of the Process Gas Supply System for Batch Processing Area" by **John K. Munson** (E. I. DuPont deNemours Co., Newark, Del.)

"Analog Components Provide an Improved Process Controller" by **William B. Field** (Union Carbide Olefins Co.)

"Scaling of Instrumentation Simulation on the Analog Computer for Control Investigations" by **Charles W. Worley** (Analog Computer Consultant, Red Bank, N. J.)

"A Digital Input Channel for the Analog Computer" by **George G. Ardell** (Union Carbide Olefins Co.)

WESTERN S/C meeting: 10 November 1960, at Norair Division, Northrop Aircraft, Hawthorne, Calif.

During the morning session a panel of experts discussed "Methods of Preflight, and Postflight Simulation." In the afternoon the practice of informal group discussions on selected topics was resumed.

Your Ed was unable to make that meeting, but *Hans Meissinger* (Chairman of the Western Simulation Council) has prevailed on some of the participants to send us summaries, so you will eventually get the word.

SOUTHEASTERN S/C meeting: 11 November 1960, ARO Inc., Arnold Engineering Development Center, Tullahoma, Tenn.

Scheduled talks:

"Limit Cycle Phenomena Experienced in Missile Nose Cone Testing" by **Dick Lowndes** (ARO, Inc.)

"Development of a Practical High-Speed Digital Simulator" by **Fred Shaver** (Marshall Space Flight Center, Huntsville, Alabama)

"Analysis of Radar Tracking System" by **Bob Nichols** (Dynatronics, Orlando, Fla.)

"Analog and Digital Methods for Analyzing and Compensating Missile Control Systems" by **Walt Lee** (The Martin Co., Orlando, Fla.)

"Simulated Altitude Testing Techniques for Rocket Propulsion Systems" by **Hugh Gardenier**

ROCKY MOUNTAIN S/C meeting: 5 December 1960, WhiteSands Missile Range, New Mexico

Scheduled talks:

"A Technique for the Determination Function Coefficients" by **W. A. McCool**

"Euler Angle Transformation Computer" by **G. R. Grado** (White Sands Missile Range)

"Electronics Environment Simulation" by **T. Katsura**

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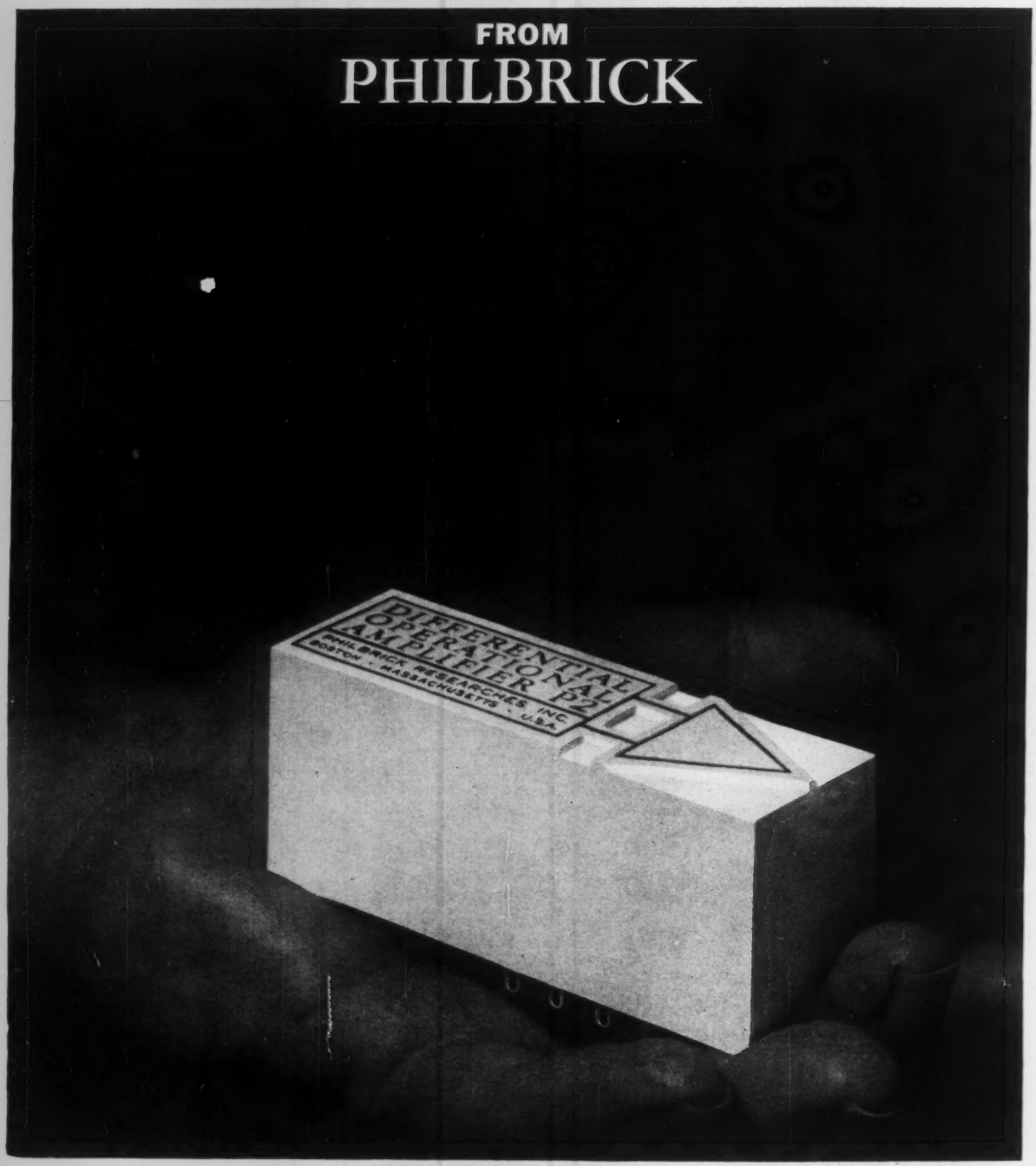

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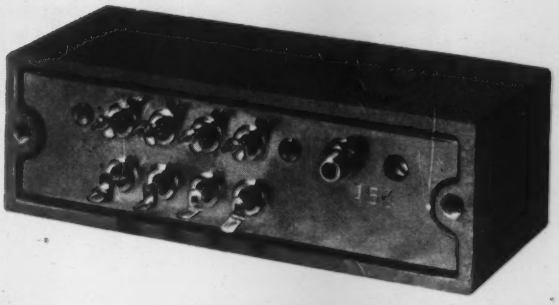


THE P2 IS UNIQUE — It is very likely that here — inside this rugged 4″ cast aluminum housing — is packed more performance and more versatility than you will find in any operational amplifier available in the world today.

A strong statement. One we're happy to back up with facts.

THESE ARE ITS FEATURES: Full differential input (truly floating with respect to ground). **Low input current** (typically less than 2×10^{-11} amp). **Low noise** (typically under 10 microvolts in the frequency range between DC and 1 KC). **Long term drift stability in sub-millivolt region. Coolness** (about 330 milliwatt dissipation). **Compactness** (4″ L x 1¼″ W x 1 11/16″ H; weight 11 oz.). **Economical operation** (no heater supply or tube replacement.) **Low price: $210**

HERE'S WHAT THE P2 CAN DO

The P2 is a dc amplifier with differential inputs, designed for analog computation and other instrument applications. These run all the way from high reliability process control to biological measurements. You can add, integrate, scale, and invert with it. Its differential inputs permit high impedance voltage following and amplification, subtraction, precise current driving to grounded loads, and many other esoteric and desirable operations.

Since inputs are electrically isolated from ground, there is no limit on the input common mode signal, except for the dielectric strength of the insulating materials. In addition, the P2's high input impedance and low input leakage accommodate the same resistors and capacitors normally used in vacuum tube circuitry: but with lower voltage ratings, greater compactness, and longer life.

Typical drift, when connected as a ten-second integrator using a one microfarad capacitor, is typically less than 100 microvolts per second.

The P2 requires 11 ma at plus and minus 15 volts from conventional supplies. Where portability is desired, it will operate continuously for about 75 hours in the field on just two pairs of small mercury batteries (TR-136 type).

SPECIFICATIONS

(Tentative)

ELECTRICAL

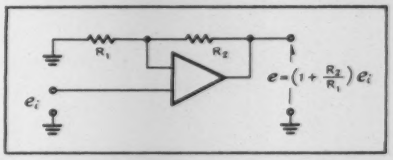
	Design	Q.C. pass limit
Gain:	30,000	20,000
Output range:	± 11V at 1.1 ma	± 10.0 volts at 1.0 ma
Minimum recommended load resistance:	10 KΩ. Will not be damaged by short circuit. Resistance loads below 10 KΩ tend to degrade the amplifier performance, but are feasible from the standpoint of safety.	
Input:		
Tolerable common mode signal level range:		± 200 volts
Admittance:	600 μμf	
Current: (at room temperature)	2×10^{-11} amp	10^{-10} amp
Drift: (referred to inputs) (20°-45°C.)	2 mv	5 mv
	typically less than 100μV in 8 hours at constant temperature	
Bandpass:	Small signal — unity open-loop gain at 75 kc	
	Large signal — output becomes amplitude limited at 1 kc	
	Output range will be reduced by 12 db/octave above 1 kc	
Power requirements:	± 15vdc at less than 11 ma (worst case load)	

MECHANICAL

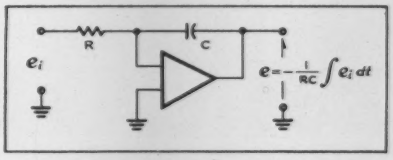
Dimensions:	4″ L x 1¼″ W x 1 11/16″ H plus ⅜″ additional clearance for terminals
Mounting:	3 11/16″ centers, 2 holes for No. 8 screws (furnished with unit)
Weight:	Mounted: 11 oz. Packed: 1 lb.
Enclosure:	Potted, cast aluminum case

For aid with your applications and for a demonstration of P2's capabilities, write, wire or phone Philbrick or your nearest Philbrick representative.

Ideal for computing instruments like these

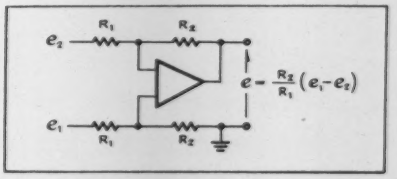


ELECTROMETER (ISOLATION) AMPLIFIER (non-inverting application): This circuit presents an extremely high dc input impedance to the source (actually higher than that of a K2-W amplifier by several decades). The gain ratio is determined by the feedback elements and is positive in polarity. Applications of this circuit include potentiometer unloading, peak-reading instrumentation, preamplification, and portable low-level electrometer-type measurements.



INTEGRATOR-MEMORY: P2's low input current and drift allow one to use high impedance values for R and C not usually considered feasible for transistor amplifiers. Considerable saving in the cost and bulk of polystyrene capacitors is inherent.

Example: R = 10 Megs and C = 1 μf gives a 10 second integration circuit.
Less than 30 millivolts error in the output is typical for a 5 minute period.



DIFFERENTIAL AMPLIFIER: The common mode rejection of this circuit is high indeed, being determined by the accuracy with which feedback ratios are maintained. Because of the input isolation, hundreds of volts of common mode signal are feasible without causing damage. The dc load on the source is almost entirely caused by the resistors alone. Using this circuit in conjunction with two pre-amplifiers of the type shown in Fig. 1, a precision differential electrometer is feasible.

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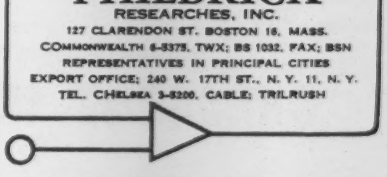

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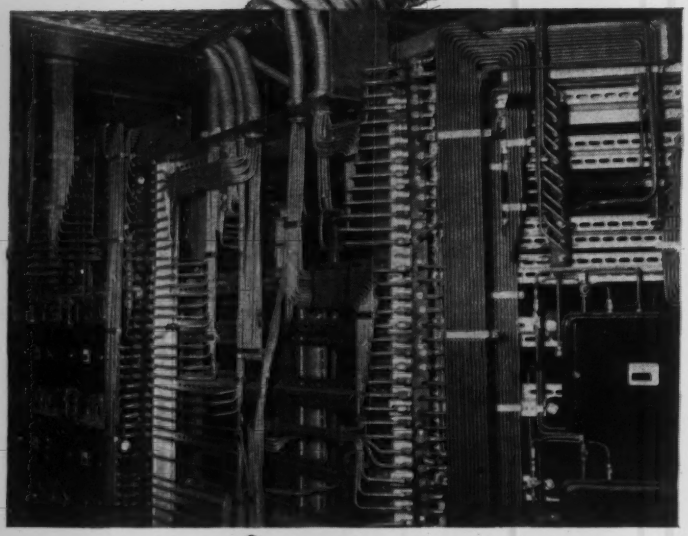
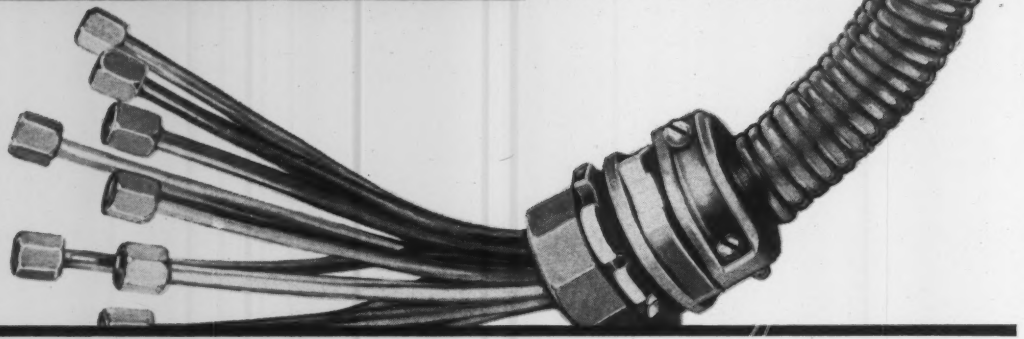
CRESCENT ARMORED MULTITUBE*



This instrument tubing panel, under the Control Room at the H. A. Wagner Station Unit #1 of the Baltimore Gas & Electric Co. has 21 Runs of CRESCENT ARMORED MULTITUBE comprising 140, 1/4 inch O.D. aluminum tubes for the long runs to this junction panel, top half of which is shown.

Aluminum tubes were used for the long runs to this point because of the lower cost of aluminum. Single copper tubes were used for the short runs from bulkhead bars to the instruments.



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CRESCENT ARMORED MULTITUBE® is a group of tubes spirally cabled together. One tube in each layer is a bright blue color, which makes identification of any tube at both ends an easy matter.

Users report savings in installed cost of from two to five times the cost of CRESCENT ARMORED MULTITUBE as compared with the old method of using single tubes. Using the MULTITUBE system will result in fewer connections and fittings, lower cost for supports or racks, ease of mounting and less space.

The spiral cabling of the tubes prevents distortion when the entire assembly is bent on a short radius. The tubing assembly is protected by a flexible, interlocked galvanized steel armor, or by a tough corrosion-resistant thermoplastic sheath or both.

Furnished in from 2 to 37 Tubes of copper, aluminum, steel, polyethylene or nylon up to 1000 feet. Also special construction for underground runs. This product is licensed under U.S. Patent 2,578,280.

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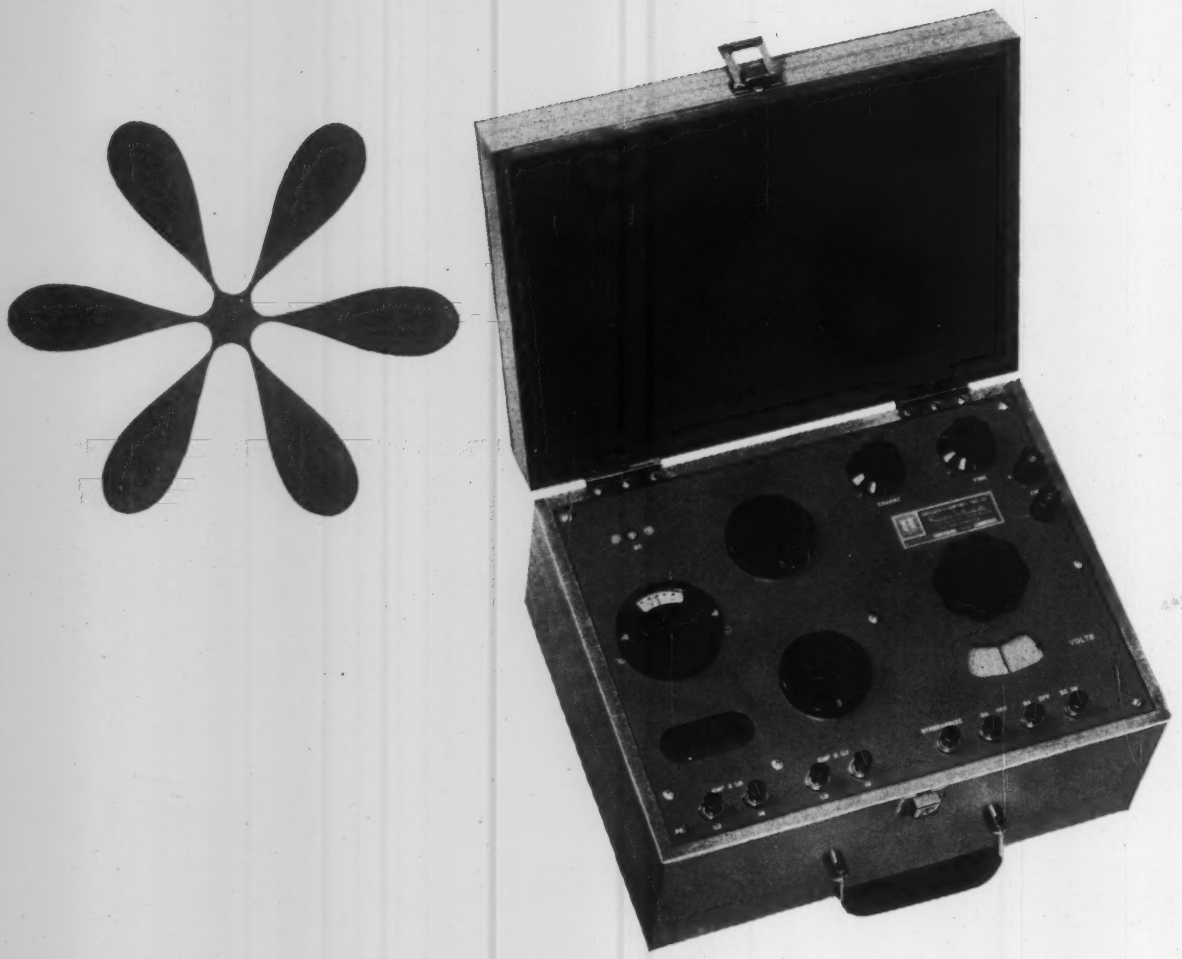

HOW SHOULD YOU EVALUATE POTENTIOMETER ACCURACY?

Accuracy in an instrument is more than a matter of how closely measured values correspond to true values. Some potentiometers, for example, may be capable of sky-high accuracy—but only under ideal laboratory conditions. Other potentiometers may deliver consistent high accuracy . . . higher than you actually need . . . with the penalty of excessive cost.

A realistic evaluation of potentiometer accuracy, then, involves consideration of stability and reproducibility as well as stated limits of error. By these criteria, Rubicon potentiometers, galvanometers and bridges should be YOUR choice.

By any measure, the new Rubicon 2746 *portable* potentiometer is an outstanding instrument. Ranges 0—1.601 and 0—0.1601 volts. Limits of error are constant, realistic, usable: high range—30 microvolts or 0.03% of reading, whichever is larger. Low range—3 microvolts or 0.045% of reading, whichever is larger. Depend on it for *consistent* accuracy. **Write for Specification Sheet RS-2746, for details.**

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The Six-Dial Thermofree Potentiometer

W. H. SCHAEFFER

Rubicon Instruments, Minneapolis-Honeywell Regulator Co.

The Six-Dial Thermofree Potentiometer can be seen in proper perspective among the potentiometers in use today by tracing the evolution of the general-purpose potentiometer from the original concepts of Poggendorf, looking at the special requirements for extending the potentiometer technique into the sub-microvolt range, and examining the means employed in the Six-Dial Thermofree Potentiometer to attain a precision of 0.01 microvolt in low-voltage measurements.

PMA MEETING NOTICE:
Wednesday, 1 March, 1961, Michael's Restaurant, 6309 East Washington Blvd. (north of Santa Ana Freeway).

Presented before the Precision Measurements Association.

IN 1841 POGGENDORF described two "compensation" methods for measuring the electromotive force of a primary cell without drawing appreciable current from it. These methods are still basic to all potentiometers. On the Continent, their paternity is recognized in the terms, such as *kompensatione apparate,* by which potentiometers are known.

Poggendorf's first method is shown in Fig. 1 where E_1 is the cell whose voltage is to be measured with negligible current drain, and E_2 is a non-polarizing primary cell. With key K open, source E_2 causes the same current to flow through resistances R_1 and R_2. The potential drop across R_1 due to E_2 is $E_2R_1/(R_1 + R_2)$. By varing R_1 or R_2 or both, we can make the drop across R_2 due to E_2 equal to E_1. At this point no current flows in the galvanometer when K is closed. At this "null point," E_1 thus is measured as a function of E_2 with no appreciable current from E_1—hence the designation of potentiometric methods as "null" methods.

Fig. 2 shows Poggendorf's method No. 2. R_1 is fixed and a tangent galvanometer (ammeter) is added to

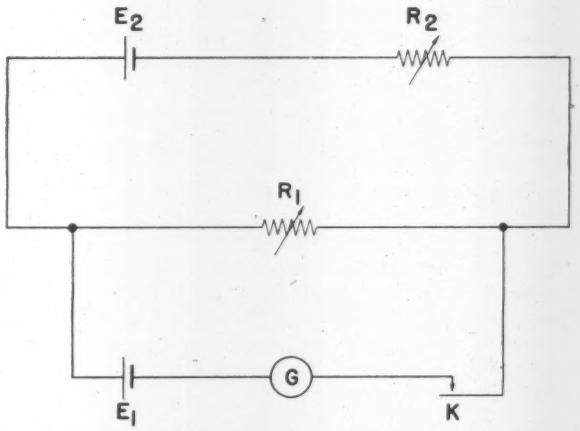

FIG. 1. WITH KEY K open, potential across R_1 due to E_2 is $E_2R_1/(R_1 + R_2)$. If E_1 equals this potential, no current will flow in galvanometer when K is closed.

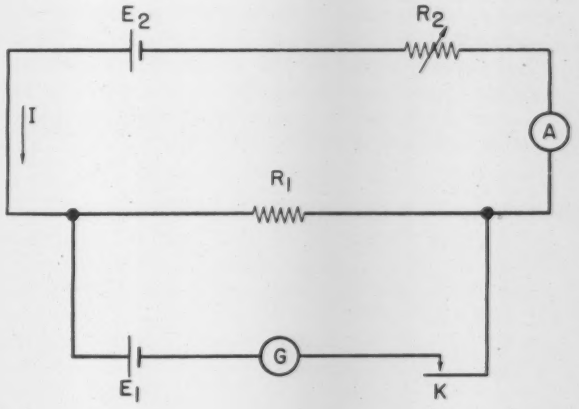

FIG. 2. AT BALANCE, $E_1 = I_1 R_1$. The current I is measured by meter A.

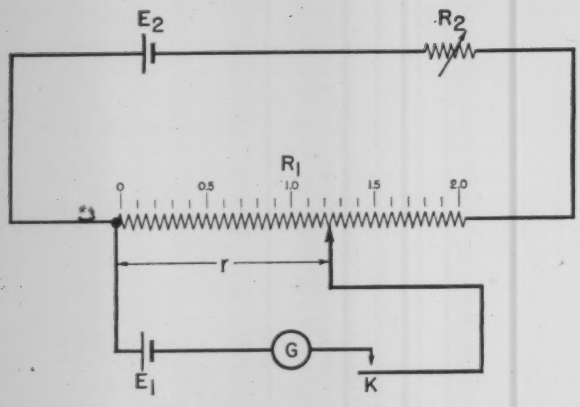

FIG. 3. CONTINUOUSLY VARIABLE slidewire, one form of "constant-current" potentiometer, was introduced by DuBois-Reymond in 1862. At balance, $E_1 = E_2\, r/(R_1 + R_2)$.

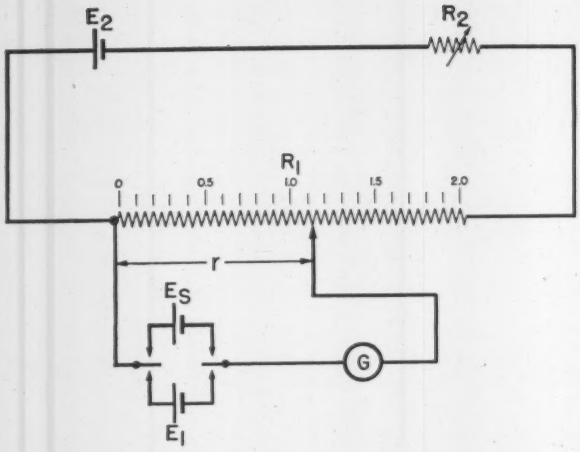

FIG. 4. LATIMER CLARK introduced the independent standard cell in 1868.

measure the current passing through R_1. To achieve balance, R_2 is varied until the galvanometer G shows null deflection. Under these conditions $E_1 = R_1 I$, where I is the current indicated by the tangent galvanometer. This method eliminates the need for repeated determination of the values of E_2 and R_1 during observations extending over a long period.

DuBois-Reymond (Variable Slidewire—1862)

Some regard Method 1 as the antecedent of constant-current potentiometers, and Method 2 as the antecedent of constant-resistance potentiometers. However, what appears to be the essential feature of constant-current potentiometers was not introduced until 1862, when *Du Bois-Reymond* described a *"Compensator"* using a continuously variable slidewire as the resistance R_1 (Fig. 3).

Du Bois-Reymond's first slidewire was a straight 2-meter length of brass wire, but he also described an instrument of more refined construction in which a platinum wire was laid in a helical groove in a cylinder of insulating material. A platinum roller was used together with a lens for accurately reading the position of the roller on the scale. This permitted the inclusion of any desired portion of R_1 in the E_1 circuit. This appears to be the first approach to a constant-current potentiometer because the manipulation required to balance the compensator causes no change in the current from cell E_2.

Latimer Clark (Separate Cells—1868)

In 1868 *Latimer Clark* described an instrument (Fig. 4) having separate cells for supplying the slidewire current and for a standard of emf. This was the first distinction between the two functions performed today by what we call the "working battery" and the "standard cell." Clark adjusted rheostat R_2 until the potential drop across the whole of R_1 equaled the emf of his standard cell, which was close to 1.5 volts. Scale readings from R then were taken as decimal fractions of the standard-cell emf, rather than in volts.

Fleming (Direct-Reading Balance—1882)

In 1882, *Fleming* made Clark's method direct reading in volts by balancing the reference cell against a suitable fraction of the slidewire scale so that the potential difference per scale division on the slidewire would equal an exact decimal fraction of a volt.

Crompton (Slidewire Range Extension—1893)

In 1893, *Crompton* constructed a potentiometer in which high precision could be obtained without the use of a long slidewire by adding 14 extension coils, each equal in resistance to the whole of the slidewire (Fig. 5). A dial switch having 15 contact points and a slidewire of moderate length were thus made equivalent to a slidewire of 15 times the length. This improvement facilitated the operation of the potentiometer, making it possible for the observer to balance the instrument more easily and quickly by providing coarse and fine adjustments. Similar arrangements are used widely in both laboratory and portable potentiometers today.

Raps (Separate Calibration-Current Resistors—1895)

Both Crompton's and Clark's potentiometers, though direct reading, required that the measuring dials be set to read the emf of the reference (standard) cell when the calibrating current from E_2 was set or checked. This was because the same resistors were used to establish the working current and to balance the unknown. In 1895, *Raps* (Fig. 6) introduced separate resistances (102, 1020 and 10200 ohms) through which the calibration current flowed. By balancing the voltage developed across each of them against the reference cell (with emf of 1.02 volts), working currents of 10, 1, and 0.1 milliampere, respectively, were established. This important improvement permitted the calibrating current to be set or checked irrespective of the setting of the measuring dials. Raps arrangement also provided 3 ranges for the potentiometer with decimal multipliers. Raps' potentiometer included 5 measuring dials, but the first use of more than 2 measuring dials antedated Raps' work, as will be seen.

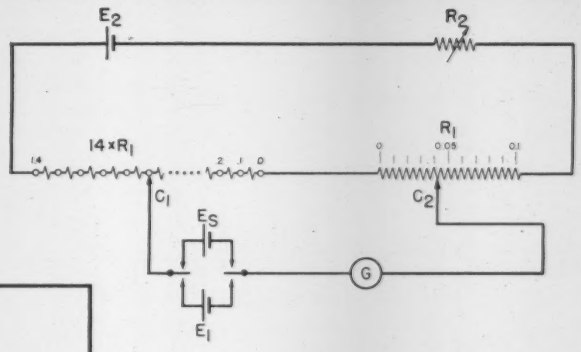

FIG. 5. IN 1893 CROMPTON made the slidewire 15 times longer in equivalent length by adding 14 resistors in series with the slidewire, each of resistance equal to the slidewire resistance. Procedure (1) Set contacts C_1 and $C_2 = E_s$. (2) Adjust R_2 to balance E_s. (3) Set contacts C_1 and C_2 to balance E_1. (4) E_1 = scale readings C_1 and C_2.

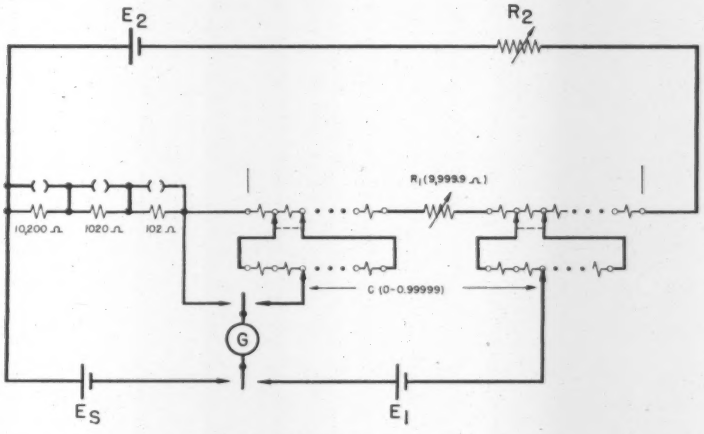

FIG. 6. IN 1895 RAPS added circuit with resistances of 102, 1020 and 10,200 ohms which, when balanced against the 1.02-volt reference cell, established working currents of 10, 1, and 0.1 ma, irrespective of setting of measuring dials. Procedure: (1) Adjust R_2 to balance E_s. (2) Set C dials to balance E_1. (3) E_1 = C dial readings (times 1, 0.1, or 0.01).

Franke (Range Changing—1897)

In 1897 *Franke* provided for range changing by means of a shunt calculated to reduce the current through the measuring resistance of the potentiometer to one tenth of its value during standardization.

L&N (Auxiliary Standard-Cell Slidewire—1906)

In 1906 the *Leeds and Northrup Company* (Fig. 7) improved upon Raps idea and introduced an auxiliary slidewire calibrated to read throughout a range of reference emfs, thus permitting convenient use of the potentiometer with any standard cell with emf between 1.0166 and 1.0194 volts.

These were the contributions leading to the development of the modern general-purpose potentiometer. All of the circuits thus far discussed* are simple ones in which no more than *two measuring dials* are used. However these circuits have one important advantage over some of the more complex circuits now to be discussed—the sliding contacts of the measuring dials carry no current at balance. (Such no-current contacts are known as potential contacts.) Therefore, no IR drop in the contacts can appear as a source of error. As we advance to potentiometers with three or more measuring dials, the problem of switch and slidewire contact resistance appears.

*With the exception of Raps.

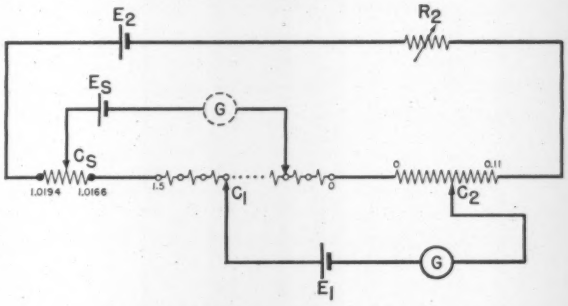

FIG. 7. L&N DEVELOPMENT, in 1906, used auxiliary slidewire to accommodate any standard cell with emf between 1.0166 and 1.0194 volts. Procedure: (1) Set $C_s = E_s$. (2) Set C_1 and C_2 to balance E_1. (3) E_1 = scale readings C_1 and C_2.

Multiswitch Circuits

Fuessner (Multiple Measuring Dials—1890)

Fuessner, in 1890, was the first to design a potentiometer having more than two measuring dials. His work led to the series of potentiometers built by Otto Wolf in Germany and to a later Fuessner type built by Eppley in the United States.

Fig. 8 shows a later Fuessner circuit with five measuring dials. The sliding contacts of Dials I and II are in the "potential" circuit and carry no current at balance. But the contacts of Dials III, IV and V carry the full potentiometer current and their IR drops appear directly in the measuring circuit. If the resistance

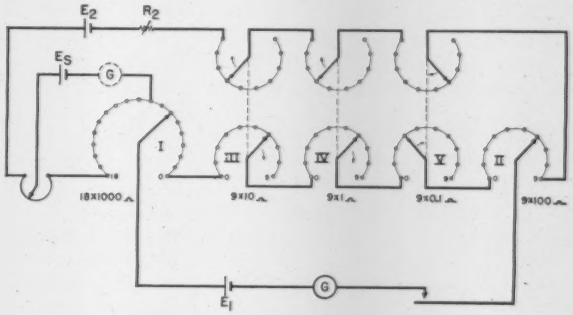

FIG. 8. FUESSNER potentiometer has two sliding "potential-circuits" contacts (I and II) which carry no current at balance. But contacts III, IV, and V do carry the working current.

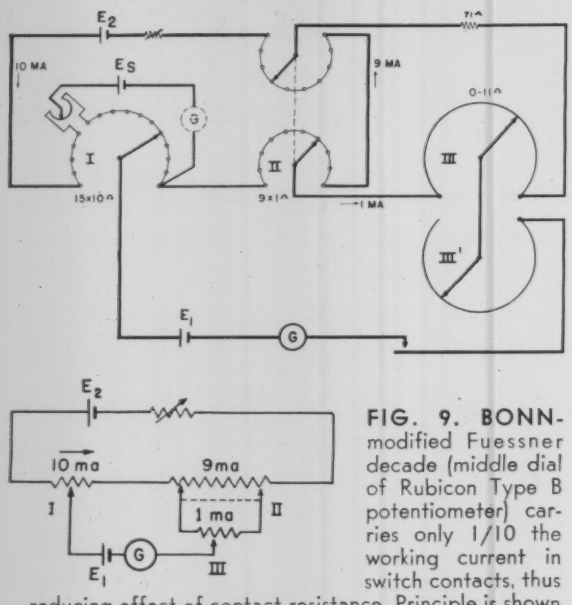

FIG. 9. BONN-modified Fuessner decade (middle dial of Rubicon Type B potentiometer) carries only 1/10 the working current in switch contacts, thus reducing effect of contact resistance. Principle is shown below.

of these switches is constant, a fixed error is introduced in the zero reading of the potentiometer; if the resistance is variable, a variable error appears in the potentiometer readings.

In order that both of these errors be small, the I of the IR term (the working battery current) is made only 100 microamperes. But this necessitates the use of relatively high-resistance elements in the potentiometer circuit, which are more difficult to make with the same stability as low-resistance elements. Also, the resistance viewed by the galvanometer varies over a wide range for different settings of the measuring dials so that maintenance of satisfactory damping becomes a problem. Further, the high resistance of the measuring circuit reduces the sensitivity of the measurement of emf's derived from low-resistance sources.

Bonn (Low-Resistance—1933)

An interesting and important modification of the Fuessner compensated decade was introduced into a 3-dial potentiometer by *Norman Bonn* of the Rubicon Company, about 1933. Fig. 9 shows this element as a part of the basic circuitry of the Rubicon Type B Potentiometer, as manufactured for some twenty years. (For clarity, the range-changing, damping and sensitivity-control circuits are omitted.) The switch in Dial II carries only 10% of the full potentiometer working current and, therefore, the IR drop is reduced to 10% of its value in an equivalent Fuessner decade. Moreover, in this instrument there is but one current-carrying *switch* (II) directly in the measuring circuit. For both of these reasons, the resistance of the Type B Potentiometer can be made much lower than that of the unmodified Fuessner. It has, in fact, a maximum resistance of about 150 ohms (as viewed by the galvanometer), compared to several thousand ohms for the conventional Fuessner.

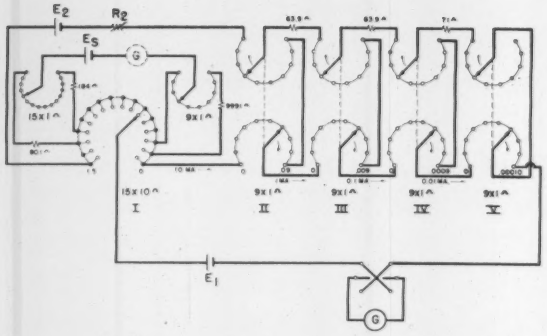

FIG. 10. BONN potentiometer uses several Bonn decades, each of which carries only 1/10th the current of the preceding decade. Use of identical resistors minimizes aging effects. Galvanometer reversing key nullifies thermal emf's in the galvanometer.

Compensation of Parasitic Thermals

Another interesting feature of the Type B Potentiometer is the use of the auxiliary slidewire III to compensate automatically for parasitic thermal emf's unavoidably generated at the main slidewire. The sliding contacts are mounted on the same arm, move together, and generate approximately equal thermals which are mutually compensating due to their reversed polarity. This technique for the reduction of thermals is suitable for a general-purpose potentiometer such as the Type B, which is not intended for measurements to much closer than 1 microvolt, but not for a potentiometer in which measurements to within one *hundredth of a microvolt* are feasible (such as the Thermofree, to be discussed).

The Bonn Potentiometer

In 1949 Bonn extended the principle of the modified Fuessner (or Bonn) decade to what we now term the Bonn Potentiometer (Fig. 10). Here Dials II, III and IV are of the modified Fuessner type. Note that the main resistors of Dial I are 10 ohms, and that the main resistors of all succeeding dials are 1 ohm each. (Ten- and one-ohm resistors happen to be among the most stable resistance coils that can be readily made.) The use of identical 1-ohm resistors in all dials following the first is made possible by the fact that each successive Bonn decade carries only 10% of the current of the preceding decade. Since the calibration of a potentiometer is a function of resistance *ratios* (rather than absolute resistance values) it is desirable to use resistances in which any residual aging effects will be uniform as to magnitude and sign—hence the advantage of using identical or nearly identical resistance coils throughout the potentiometer.

In order to keep the resistance viewed by the galvanometer relatively constant for all potentiometer readings, Dial I is provided with compensating resistors. To minimize parasitic thermal emf's to a degree consistent with the range of this potentiometer,

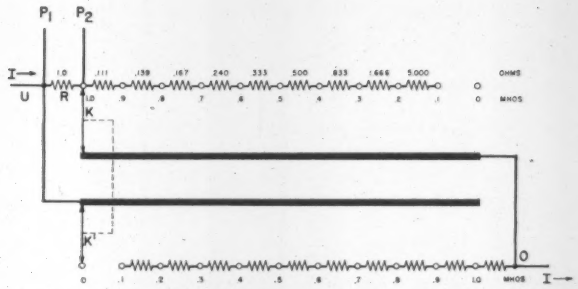

FIG. 11. HAUSRATH element uses ganged switch that adds resistance in one arm as resistance is switched out of the other, keeping total resistance (and I) between input (U) and output (O) constant and independent of switch position. However, emf across resistor R (P_1P_2) varies with brush position. Thermals in the P_1 P_2 circuit are reduced because switch contacts are in a parallel circuit of relatively high resistance.

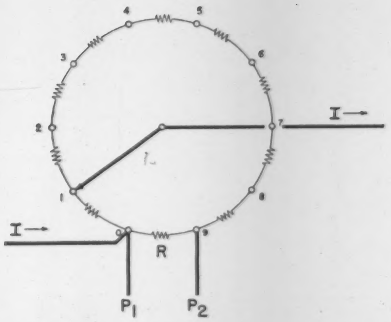

FIG. 12. DIESSELHORST RING principle. Switch contacts are excluded from P_1 P_2 circuit. Current division between R and remainder of ring depends only on resistances of ring and switch position; is unaffected by switch contact resistance.

the switch contacts of Dial V (which is the last to be manipulated in arriving at balance) are placed in the battery (E_2) rather than the galvanometer (zero-current E_1) circuit. There a parasitic thermal emf of even 1 microvolt would be only 1 part in 6,000,000 of the battery voltage, and its effect would, therefore, be negligible. If it were to appear directly in the galvanometer circuit, however, it might become a significant source of error. We shall see more of this technique of placing switch contacts in the battery rather than the galvanometer circuit in the discussion which follows.

Instead of using a calibrated slidewire for setting the standardizing resistance of the potentiometer to various standard cell emfs, two dial switches are employed for this purpose, permitting adjustment to within 5 microvolts of the certified value of the standard cell—i.e., to within 5 parts per million.

In the Bonn Potentiometer, and also in the Type B Potentiometer, the working current is always standardized against the measuring resistors of Dial I. To the extent that the standardization and measurement involve the same resistors, and the same range, any error in resistance values is eliminated as an error in the potentiometer reading, and the attainable accuracy approaches that with which the emf of the standard cell is known.

Note also the galvanometer reversing key in Fig 10, for eliminating the effect of thermals in the galvanometer and its leads. Conventionally the galvanometer key merely closes and opens the galvanometer circuit and permits no ready discrimination between signal voltage and thermal emf's. But the reversing key changes the polarity of the signal voltage while maintaining that of the thermals in the galvanometer branch. Therefore, by balancing the potentiometer until the *change* in deflection of the galvanometer is made zero, upon operation of the reversing key, the potentiometer reading is made independent of the thermals in the galvanometer circuit—despite the fact that the galvanometer may be deflected considerably from its open-circuit position. (Of course the key must introduce no significient thermal effects of its own.)

An incidental advantage of the galvanometer reversing key is the effective doubling of the sensitivity of the galvanometer. If a galvanometer shows a deflection of, say, 2 millimeters for a signal of 0.1 microvolt, it will show a net deflection of 4 millimeters for reversal of the same signal.

EMFs in Switch Contacts

As early as 1905 attention was paid to the reduction of parasitic emf's resulting from sliding contacts. At that time *Hausrath* proposed the circuit element shown in Fig. 11. Here the working current (I) enters at U and leaves at O. For any position of the mechanically linked brushes, the total resistance from U to O remains at 1 ohm so that the *total current* remains unchanged. But, as the brush K takes the positions 1.0, 0.9, 0.8, etc., the *fraction* of the total current carried by the 1-ohm resistor between P_1 and P_2 is 1, 0.9, 0.8, etc. Thus the potential drop between P_1 and P_2 is varied with the brush positions *without changing the total current in the element.* As there are no switch contacts directly in the P_1P_2 circuit, the effect of switch thermals is reduced—but only to about 25% of their full value, for the least favorable position of the brushes. Further, the division of current in the two branches of this circuit is vulnerable to variation in the switch contact resistances. Further, the number (and odd values) of the resistors add objectionably to the cost of this element.

Diesselhorst Ring

In 1908, *Diesselhorst* described the "ring" element which has subsequently been known as the *Diesselhorst ring*. Fig. 12 shows one part of the Diesselhorst ring—a series arrangement of 10 equal resistors. The current I enters at O and leaves via the switch brush. When the switch is at zero position the potential drop across P_1P_2 is zero. At position 1, one tenth of the total current (I) flows through resistance R, and nine tenths through the first resistor of the ring. The potential drop across P_1P_2 is then 0.1(I). At position 2, two tenths of the total current flows through R and eight tenths through the first two resistors of the ring. The potential drop across P_1P_2 is then 0.2(I); etc. It remains necessary only to add compensating resistors to keep the total current I constant for all switch positions, to arrive at the Diesselhorst ring. This is done

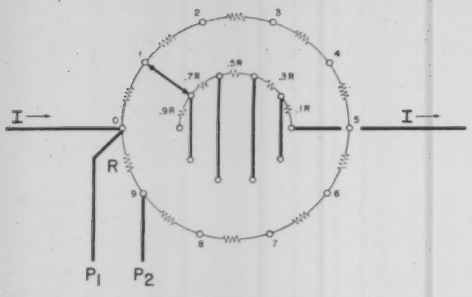

FIG. 13. DIESSELHORST RING element includes compensating resistors for keeping total current constant at all switch positions.

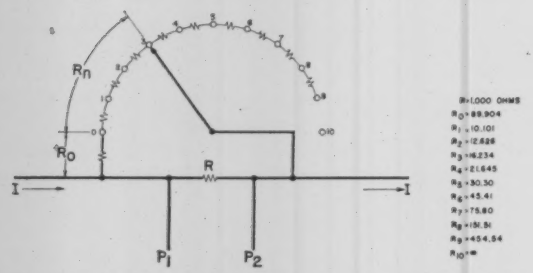

FIG. 14. WAIDNER-WOLFF element uses large resistance values in series with contacts, but low resistance R in measuring circuit. Hence effect of contact resistance, and thermal emf's in the switch, is small.

as shown in Fig. 13, which shows the complete Diesselhorst ring. Because of the symmetry of the ring, the values of the compensating resistors repeat, so that the same resistor may be used for compensating two different switch positions.

In a Diesselhorst element the division of current in the ring is independent of switch contact resistance and is a function only of the fixed resistance *ratios*. Thermals due to operation of the switch appear only in the battery circuit and, with good design, will affect the potential drop across P_1P_2 to less than one part in a million. The Diesselhorst ring (either as described or somewhat modified) is used in all the measuring dials of the Six-Dial Thermofree Potentiometer.

Waidner-Wolff Element

In 1907, *White* suggested the use of the *Waidner-Wolff element*, previously used in resistance apparatus, as a potentiometer element. This element (Fig. 14) consists of a fixed resistance R shunted by a relatively high resistance, adjustable from a minimum value (R_0) to infinity. The shunt resistors are of such value that the resultant total resistance of the element is changed by equal small steps (e.g., 0.001 ohm) as the switch position is changed. The potential drop P_1P_2 therefore changes by uniform small steps if the current I is constant. This arrangement makes the effect of contact resistance small since it is in series with a large resistance. At the same time thermal

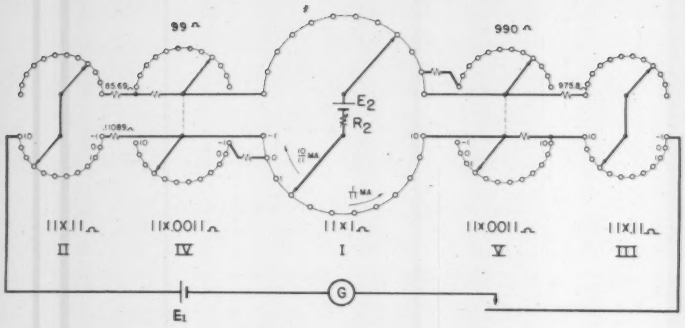

FIG. 15. DIESSELHORST "Thermokraftfrei" Potentiometer uses split circuit in which unknown emf E_1 is balanced by the difference in potentials of points on the two branches of the divided circuit. Dials IV and V are of a dual (resistance-compensating) Waidner-Wolff type.

emfs due to the switch are attenuated in the ratio $R/(R + R_0 + R_n)$. In the element shown, thermals in the switch would manifest themselves in the measuring circuit only to about one ninetieth of their actual value. The Waidner-Wolff element is an important element of the Mueller Bridge.

In 1908, Diesselhorst designed a five-dial potentiometer (Fig. 15) in which all dial switches were removed from direct series connection in the galvanometer circuit, in order to effect a substantial reduction in the thermal emfs which would otherwise be present in the measuring circuit. This instrument, known as the *Thermokraftfrei Kompensatione Apparate* (Thermoforce-free Potentiometer) can be described as a difference, or split-circuit, potentiometer since it makes use of a divided circuit in which the unknown emf is balanced by the *difference* in potential of points on the two branches of the divided circuit. The resistances are such that the left-hand branch (containing Dials II and IV) carries 10/11* of the total current. With a standardized current of 1 milliampere, the range is 10,000 microvolts in steps of 0.1 microvolt. Dial I controls the position of the branch points at which the potentiometer current (from E_2) splits. The switch contacts are directly in series with the battery, where parasitic thermals become negligible in comparison with the battery voltage. Dials IV and V are of the Waidner-Wolff type (shown in Fig. 14) where the effective thermals are attenuated to about 1% of their actual value. Thermals generated at Dials II and III can reflect themselves in the galvanometer circuits to about 1.3% of their actual value. Assuming thermals of the order of 1 microvolt in the switches, their effect in the main measuring circuit should not exceed a few hundredths of a microvolt.

Wenner Element

In 1910, *Wenner* devised a circuit element (Fig. 16) to eliminate the large number of resistance coils which must be adjusted to odd values in the Waidner-Wolff element. The upper and lower series of resistors (a)

*The right-hand branch, containing Dials III and V carries the remaining 1/11 of the total current.

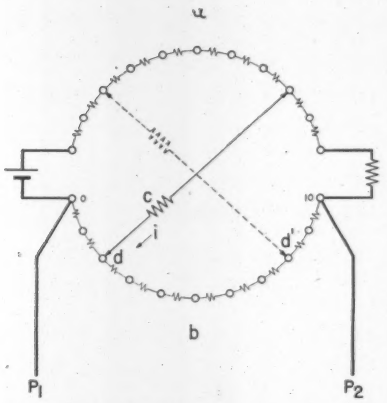

FIG. 16. WENNER ELEMENT maintains constant current, like the compensated Waidner-Wolff element, but uses identical resistors. Effects of contact resistance and switch thermals are minimized.

and (b) are identical and consist of 10 equal steps each. The resistance (c) between the contact points on the switch is fixed in value. Hence the resistance of the element as seen from the battery is constant (hence I is constant). As the switch is moved from d to d′ the current in that part of b between d and d′ changes by an amount i (carried by c), while the current is unchanged in the remaining parts of b. The change in potential drop between P_1 and P_2 is then the product of i and the resistance from d to d′. Since the resistance of each of the ten steps is equal, it will be seen that the potential difference from P_1-P_2 changes with dial positions in 10 equal steps. Thermal emf's in the switch are reflected in the potential difference between P_1 and P_2 to less than 1% of their value, and the effect of contact resistance is small by virtue of its occurrence in series with the large resistance c.

In the early thirties, or late twenties, Norman Bonn, at that time associated with the Leeds and Northrup Co., designed a five-dial potentiometer of the difference (or split-circuit) type, using two Wenner elements, and since known as the *Wenner Thermocouple Potentiometer* (Fig. 17). Dial I is similar to Dial I of the Diesselhorst Thermokraftfrei Potentiometer (Fig. 15). In both, all switch contacts are in series with the battery voltage and reflect themselves in the main measuring circuit to only a negligible extent. Dials II and III are Wenner elements, as discussed. Thermal emf's in the switches are reflected in the galvanometer circuit to probably less than 1% of their actual value. The contacts of dials IV and V are in series with relatively high resistances, and their thermals are correspondingly attenuated in the main measuring circuit.

In both the Wenner and the Diesselhorst potentiometers, the measured emf, which may be quite small, is developed as the difference of two relatively large emf's. Any error in either of the opposing emf's can, then, be manifested as a much larger proportional error in their difference. This is a fundamental short-coming of the difference potentiometer. In the Wenner potentiometer (Fig. 17), it is true that the rheostat R_1 permits adjustment of the ratio of the currents in the two branches to its proper value for a given setting of Dial I, and that the dual rheostat R_2 permits compensation for inequalities and residual thermals when the dials are set on zero, but the problem of validating the adjustment and compensation for other dial settings remains.

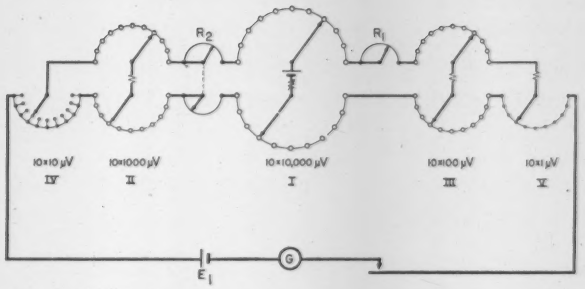

FIG. 17. WENNER low-range difference potentiometer.

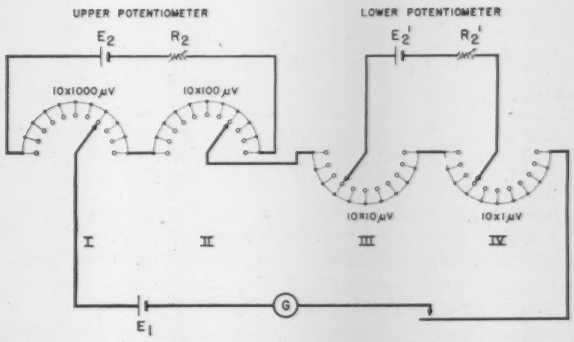

FIG. 18. WHITE potentiometer comprises two potentiometers in series, with independent standardizing circuits.

The White Potentiometer

In 1914, *White* suggested a "combination" potentiometer for thermocouple work, consisting essentially of two potentiometers in series connection, each with its independent battery and standardizing circuits (Fig. 18). Dials I and II of the "Upper Potentiometer" are directly in series with the galvanometer, but it has been urged that their inclusion in this thermally vulnerable circuit is admissible because thermals induced by movement of the switches will dissipate before Dials III and IV are adjusted for final balance. Also, in at least some instances, the switches have been made with all current-carrying parts of copper to minimize thermal emf's. The contacts of Dials III and IV are in the battery circuit of the lower potentiometer, where thermals have no appreciable effect in the measuring circuits.

Microvolt Potentiometers

Despite the number and variety of potentiometers discussed and available, increasingly greater precision is required. In 1937, Rubicon encountered a need (in the Fixed Nitrogen Laboratory of the United States Department of Agriculture) for measuring thermocouple emf's to within 0.01 microvolt. This led to a

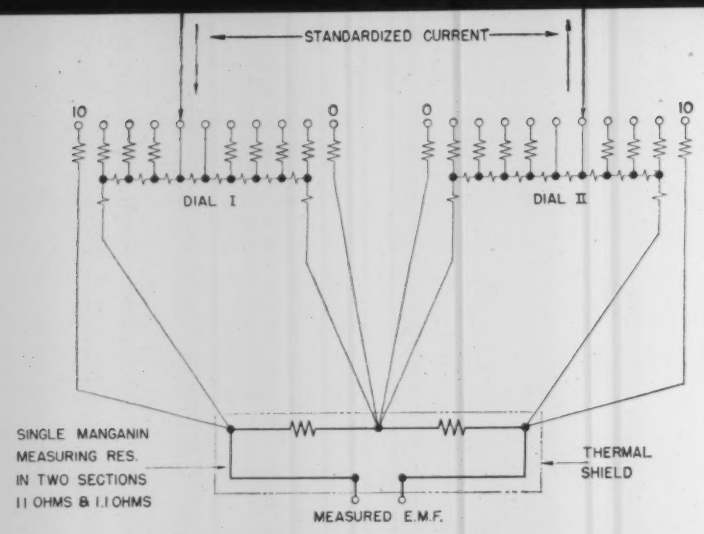

FIG. 19. THERMOFREE potentiometer element has only one manganin resistor in the galvanometer circuit.

series of "Microvolt Potentiometers" and ultimately to the evolution of the Six-Dial Thermofree Potentiometer, as we know it today. These instruments use two measuring dials to cover 99% of their ranges and a milliameter calibrated in terms of microvolts to cover the remaining 1% of their ranges. The milliameter reads current in a "Lindeck element" (merely an application of the second method of Poggendorf). Several models are listed, in single and double forms, with full scale ranges of 1000, 10,000 or 100,000 microvolts. For most purposes, the Microvolt Potentiometers are superseded by the Six-Dial Thermofree Potentiometers.

The Six-Dial Thermofree Potentiometer

General-purpose potentiometers have ranges extending to about 1 or 2 volts, with low ranges permitting the measurement of low emf's with a reliability of about 1 microvolt. Sliding contacts are used directly in the galvanometer circuit because there is no purpose in using more specialized and costly designs for work at the voltage levels for which these instruments are intended.

For low ranges down to 0.1 microvolt, we have examined the Diesselhorst Thermokraftfrei (Fig. 15) and the Wenner Thermocouple Potentiometer (Fig. 17) in which sliding contacts are removed from the galvanometer circuit. These have dial readings down to 0.1 microvolt, and can be expected to be free of thermals to within about the same level.

To extend the range of measurement downward by another order of magnitude—down to a level of 0.01 microvolt—other sources of thermal emfs within the potentiometer must be recognized and eliminated, or at least reduced by a factor of 10 or more.

First, in the basic multidial circuits, scores of manganin-solder-copper junctions are used directly in the galvanometer circuit. In the presence of thermal gradients which are almost always present (due to body heat of the operator, if for no other reason), these junctions are prolific generators of thermoelectric force. Even a single copper-manganin junction generates about 2 microvolts per degree; the magnitude of the problem is evident.

In the Six-Dial Thermofree Potentiometer* (Fig. 19) there is but a single manganin resistor directly in the galvanometer circuit, and the junctions of the resistor with the copper leads completing the circuit are brought together in close proximity for temperature equalization. The resistor and its connections are mounted in a heavy, compact, cast-aluminum thermal shield which assures a high order of temperature equality for these connections. The heavy line between 1 and 2 represents a single manganin resistor tapped to form two sections. Each of these sections is made part of a Diesselhorst ring, which is completed by the resistors of Dials I and II, respectively. Thermoelectric forces generated by connections in the ring manifest themselves only to a small extent in the main resistor.

Fig. 20 shows the extension of the ring arrangement to the six-dial circuit. In effect, three distinct potentiometer circuits are used, each developing a potential drop across its own section of a single manganin resistor. The current for the first two dials is derived from a 6-volt storage battery (BA1), for the middle two dials from a No. 6 dry cell (BA2), and for the last two dials from an internal mercury-cadmium cell. The three currents are 10 milliamperes, 1 milliampere, and 12 microamperes, respectively. The currents in the upper and middle two dials are standardized in the usual way by reference to an external standard cell. The current from the internal mercury-cadmium cell is sufficiently stable to require standardization only at long intervals; the operator need concern himself with standardization of only two, rather than three, potentiometer currents.

Other sources of thermoelectric effects which must be considered are the galvanometer key, the terminals for connecting to the measured source of emf and to the galvanometer, and any switching which must necessarily be carried out in the galvanometer circuit, such as switching from one source of emf to another. The galvanometer reversing key eliminates the effect of thermal emf's in the galvanometer circuit itself, as described previously. However, care is required in the design of a key to preclude thermals of the order of 0.01 microvolt. In the Six-Dial Thermofree Potentiometer, all current-carrying parts of the key are pure copper, except the contacts themselves, which are gold.

*Designed by Bonn in 1939.

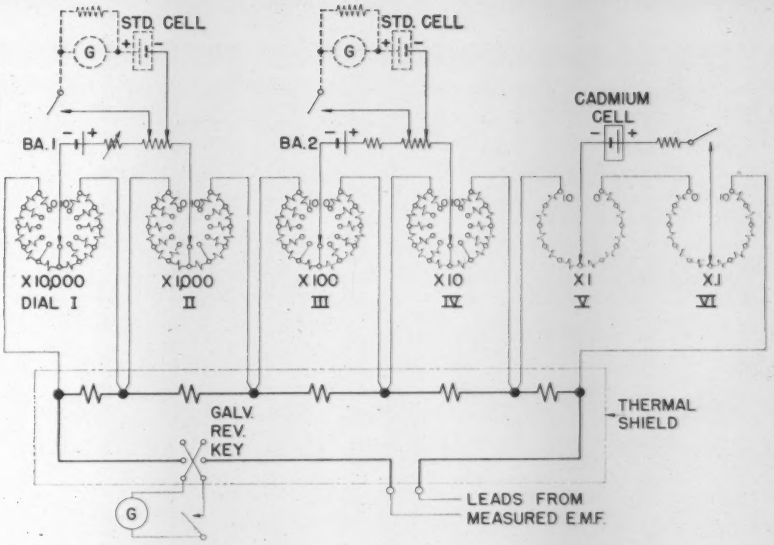

FIG. 20. SIX-DIAL THERMOFREE potentiometer.

The copper blades are clamped between heavy copper blocks with mica insulation for temperature equalization, and the contacts are arranged so that the minute emf generated at one is opposed by a similar emf produced at the other. High thermal impedance is placed in the path of heat flow from the observer's finger to the reversing key, and provision is made for distributing such heat as is conducted into the key equally to opposing contacts. In addition, the key is mounted in the same heavy cast aluminum temperature-equalizing enclosure that houses the main resistor. A selector key for switching the measuring circuit from one source of emf to another is similarly constructed and is also mounted in the thermal shield.

Leads entering the shield from the outside resistance networks are of manganin to impede heat flow along these paths. They, too, are brought into thermal contact with the shield to further reduce heat flow to the thermally vulnerable elements within the shield.

The net effect of these thermal reducing techniques is to hold the thermal content of the potentiometer proper well below 0.01 microvolt, and to afford means to eliminate the effect of thermals in the galvanometer circuit to within the same level.

The Six-Dial Thermofree Potentiometer is built as a "single" potentiometer and a "double" potentiometer, the latter being provided with a duplicate set of six measuring dials and a master switch to permit measurement in rapid succession of two distinct voltages which may vary widely from each other. Both single and double potentiometers are two-range instruments. The upper range is 0 to 110,000.00 microvolts in steps of 0.1 microvolt; the lower, 0 to 11,000.00 microvolts in steps of 0.01 microvolt. The limit of error on the upper range is 0.01% of reading plus 0.1 microvolt; on the lower 0.01% of reading plus 0.01 microvolt.

Other characteristics include: First, the potentiometer has a true and stable zero, rather than one formed by opposing two relatively large emf's. No adjustment is necessary, possible or desirable. Similarly, the calibrated emf is developed directly rather than as a difference between two opposing emf's, where errors in either can result in much larger proportionate error in their difference. Calibrations also can be performed more readily than with difference potentiometers.

Second, the resistance presented to the EMF and GALVANOMETER terminals is substantially constant at 13 ohms, with little or negligible change in sensitivity or damping of the galvanometer for different positions of the dial switches.

Third, recent re-design of the potentiometer has made practical great improvement in the shielding and guarding of the potentiometer circuit against electrostatic and leakage effects, generally induced by the operator. This improvement, especially significant in work with high-impedance sources, e.g. germanium and carbon resistance thermometers, is welcomed by anyone who has attempted to work at signal levels of the order of 0.01 microvolt, however low the impedance of the source.

Applications

The highly specialized construction required to hold parasitic thermal emf's below 0.01 microvolt is costly and is justified only where an accuracy or precision extending below 1 microvolt is desired. In the field of cryogenics, the instrument is used in the determination of the resistivity and thermal conductivity of metals at low temperatures, and for the determination of temperature by resistance thermometers of one form or another. Its application to the measurement of thermocouple emf's is obvious. The instrument also has been used in Hall-effect studies.

In applications where serial readings of the potentiometer must be made over a long period of time, as in heating or cooling curve studies, it may be desired to relieve the operator of the necessity of transcribing hundreds of dial readings to data sheets. Supplementary switching, synchronously controlled by the main dial switches, can actuate automatic print-out or punching devices at the command of the operator. The instrument is still balanced manually, but the chore of manual data transcription is eliminated.

Acknowledgement

Appreciation is expressed to John Wiley and Sons, Inc., for permission to use material from their publication, *ELECTRICAL MEASUREMENTS*, by Forest K. Harris.

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MS-10	4000-7300	50 MW	50 MW
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Direct-Reading Resistance-Thermometer Bridge

J. SUTCLIFFE
Guildline Instruments Ltd.

FIG. 1. DIRECT-READING resistance-thermometer bridge Type 9500 in use at National Research Council, Ottawa, Canada, for use in conjunction with a platinum resistance thermometer to read the temperature in any one of four temperature-controlled baths. Liquid-in-glass thermometers under calibration are read through the telescope.

A DIRECT-READING resistance-thermometer bridge has wide application in determining temperature between −50°C and +711°C and in calibrating thermocouples and liquid-in-glass thermometers. In this temperature range it largely supersedes the Smith and Mueller bridges which read out in ohms and require extensive computation to convert from ohms to degrees. It also avoids the difficulty associated with maintaining stable current in two independent circuits, as is necessary in the use of a potentiometer to compare the resistance of the thermometer with that of a standard resistor.

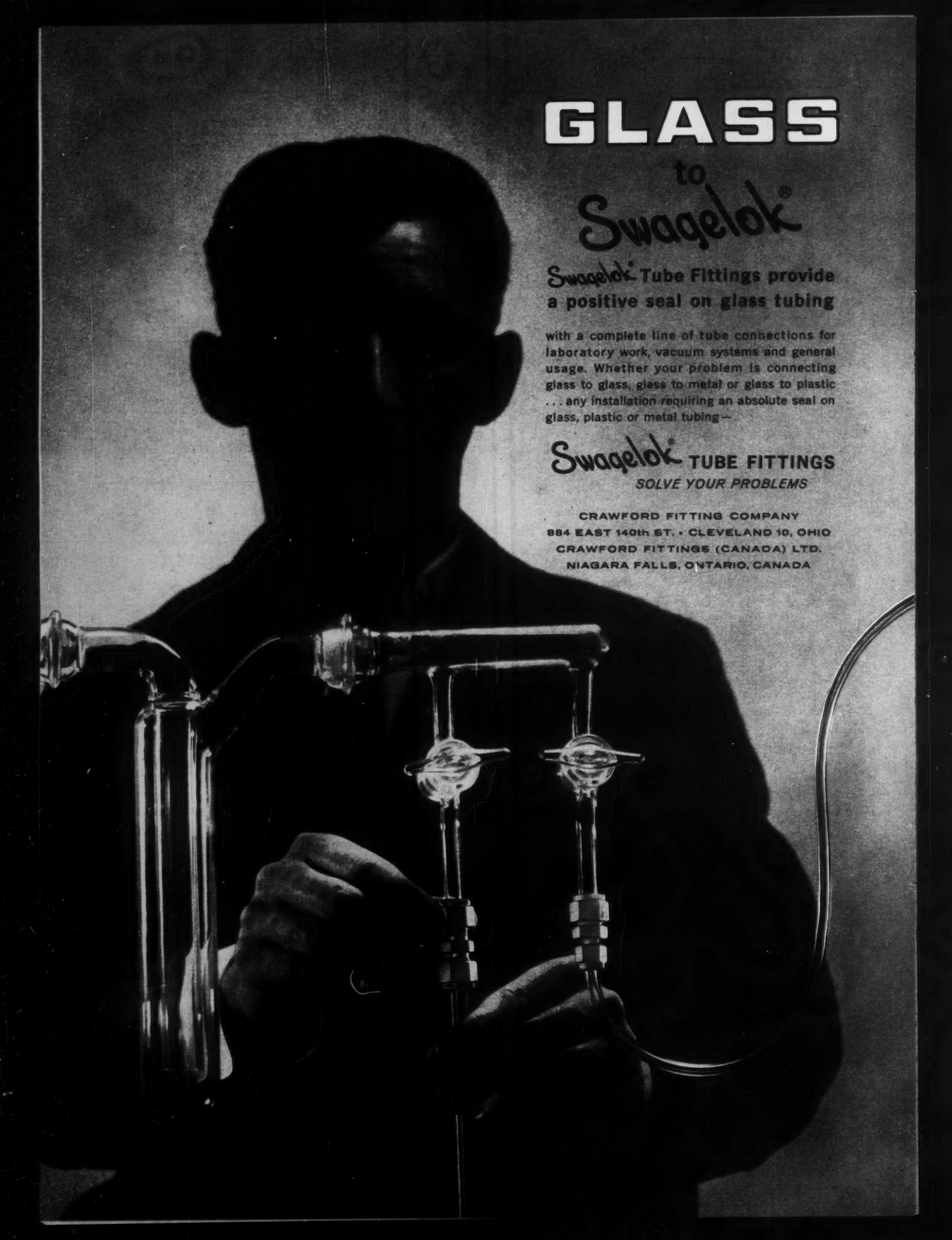
The first instrument of this type was produced in 1957 (by Guildline Instruments Ltd.)* for the National Research Council in Ottawa, Canada in accordance with a design by Dr. T. M. Dauphinee and Dr. H. Preston-Thomas of the Division of Applied Physics. Since that date the bridge has been in continuous use in thermometer calibration (Fig. 1).

The bridge can be constructed with provision for constant deflectional sensitivity. This makes it possible to use the bridge with a chart recorder to indicate graphically the reading of the lower two decades and to maintain the same output in millivolts per degree for all settings of the upper decades.

The Type 9500 bridge is a six-dial resistance-thermometer bridge reading directly in Centigrade degrees. Using any standard 25-ohm platinum thermometer the bridge subdivides the temperature scale in increments of 0.001C° from −50°C to +711.110°C, with an error (excluding that of the thermometer) not greater than ±0.001C°. It is possible to use any standard 25-ohm thermometer with the bridge—the "A" and "B" constants of the thermometer and the ice-point resistance can be set on bridge dials. The "C" constant, which is applicable to temperature readings below the ice point, is permanently set in the bridge network.

The instrument includes a voltage comparator that compares the potential across the thermometer element with the potential across the variable bridge resistors when the two are connected in series with the internal dry battery. The comparison is by a potentiometric method and is therefore independent of lead resistance. In addition, the circuit is independent of current drift. The thermometer can be located at a point remote from the bridge without affecting accuracy. All important resistors in the bridge circuit are enclosed in an aluminum block, which is temperature controlled at 28°C. The only external equipment necessary is a sensitive null detector.

*Manufacturing rights are held by Guildline Instruments Ltd. (formerly Tinsley Instruments (Canada) Limited) under license from the Canadian Patents and Developments Corporation. Exclusive marketing rights in the United States are held by Sensitive Research Instrument Corporation. Design details are given by Dauphinee and Preston-Thomas, *Review of Scientific Instruments*, Vol. 31, No. 3, pp 253-263, March 1960. Reprints are available from Sensitive Research Instrument Corporation.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THOMAS J. FILBAN
Daniel Orifice Fitting Co.

The Orifice Flow Section For Metering Low Rates Of Flow

IN 1957, the Daniel Orifice Fitting Co. constructed a small flow laboratory to investigate the possibility of applying known orifice meter practices, applicable to the larger sizes, to a miniature counterpart with a view toward determining if there was a possibility of designing a unit whose performance would be predictable.

There is today a vast compilation of knowledge concerning the orifice meter. Its characteristics, accuracy, repeatability, predictability, have been studied with great interest for many years. Its range and scope have been constantly extended; its evolution from a crude metering device to the present refined instrument is the end result of this continued interest and study. All this attention, however, had been directed to those orifice meters of two inch size and larger, with relatively large flow rates. The limits within which a predictable accuracy of ½ per cent might be found were limited to an actual orifice size of approximately 0.300 inch, much too large to generate a readable differential pressure at low rates of flow. True, many measurement engineers reasoned that if coefficients could be calculated for 2-inch sizes in schedule 40 pipe or schedule 80 or even schedule 160 pipe with ever-decreasing diameters, they might likewise be calculated in successively smaller sizes with perhaps a lesser degree of expected accuracy.

Original research data on the orifice meter was consulted; throughout these writings, one theme was apparent. The predictability, the repeatability, of an orifice meter within certain defined tolerances is based simply on the degree of exactness by which orifice meters may be duplicated and which, in turn, duplicate the empirical data on which the coefficients are founded. The first step in the transition from a custom-designed item to a piece of standard hardware was thus defined before the prototype actually came into being: rigid quality control on all components of the meter. On the theory that near-perfection would be easier to attain than some in-between point, the internal roughness of this prototype meter tube was set at 20 microinches or better; this same limiting value was applied to orifice plate surfaces. Out-of-roundness and diameter tolerances were specified as 0.001 inch for tubes and 0.0005 inch for orifices. The orifice edge thickness was fixed at 0.02 of the tube diameter (a figure recommended by ASME for larger tubes).

A study of existing data on pressure gradients in the vicinity of the orifice led to the conclusion that corner taps would be most advantageous. It appeared that in tubes of this small diameter, such a location would avoid the possibility of having the downstream tap located in the rapidly changing pressure-recovery area. The phenomenon of pressure build-up on the upstream side of the orifice was considered, but discounted in the belief that the flow calibration would take care of this effect.

Initial laboratory studies were carried out on tubes of one-inch size with the thought that the performance of such tubes should not depart too radically from those of larger size. A pair of tubes which were as nearly identical as could be determined in internal diameter and roughness were tested with six orifices of varying sizes. By conducting similar tests on the two identical tubes with a common orifice, it was considered that any difference in the resultant flow coefficient at the same Reynolds Number should be attributable to only accidental errors of observation. The results of this early work were very promising, so much so that the scope of the tests was extended to include ¾ inch size also. (It was at about this time that the term "orifice flow section" was applied to these small instruments to distinguish them from the larger pipe-fabricated meter tubes.)

10TH ANNUAL INSTRUMENT SHORT COURSE —SCMA and Los Angeles Harbor Junior College
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The results of some two years of laboratory testing have been discussed in another paper.* It is certainly worth noting here, however, that as a result of this work it was found that a general equation could be written describing all tests on both ¾″ and 1″ flow sections within an arithmetic difference of 0.4 per cent:

$$K = 0.6025 + 0.343\beta^4 + (0.00075 + 0.013\beta^4)\lambda$$

where K is the familiar flow coefficient, β the ratio of orifice diameter to pipe diameter and $\lambda = 10^3/\sqrt{R_D}$, R_D being the pipe Reynolds Number. The average standard deviation between computed and observed values is ±0.5 per cent.

As industry became aware of this program through discussion at various meetings, interest increased accordingly. Long before the completion of the program, a flood of inquiries relating to rates of flow which would require even smaller sizes had been received. As a result of these inquiries, an investigation of the feasibility of extending the range downward through ½ and ¼ inch sizes was conducted. Numerous tests of the ½ inch size have led to the conclusion that some additional factor taking into account pipe size must be added to the existing general equation in order to obtain something near the same predictability. Orifice sizes calculated by this equation for the ½ inch flow section have been found to agree within approximately 1 per cent of the calibrated value. When it is considered that an error of 0.0005 inch applied to an orifice bore of 0.200 inch results in an error of ½ per cent in area, it is apparent that the earlier-mentioned rigid quality control becomes extremely important. The standardization of these instruments with a predictable accuracy tolerance within certain limitations has now been well defined. Our efforts from now on are directed toward the attainment of still greater accuracies through the medium of individual laboratory calibrations.

Of all basic research tools used in the investigation of fluid dynamics and associated phenomena, the well-equipped flow calibration laboratory in the hands of experienced personnel is probably the most important. The investigation of the small flow sections described above and their evolution to a standardized instrument constitute a very good example of this fact. There are size limitations to be considered, of course; to design a laboratory to meet the exceptional problem, particularly where larger flow rates are concerned, would probably require a greater cash outlay than would be justifiable. Again, however, a laboratory designed for the norm and in the hands of experienced personnel may, by simulation of certain flow conditions through proportional flow and scale miniaturization, cover an extremely wide range. The simulation of flow conditions may be accomplished by virtue of Reynolds Number alone which, by reason of its dependence upon all the factors governing flow rate (diameter, velocity, density and viscosity) may be changed at will by changing one or more of the various factors. Since the flow coefficient is a function of Reynolds Number, it matters but little whether the calibration employs the same fluid as that which will be metered. For some very extreme conditions, for some non-Newtonian fluids, the above may not be strictly applicable. In these very exceptional cases, a special device may be necessary—in which case, the laboratory becomes even more essential.

There is a present-day trend toward a calibrated system accuracy rather than on calibrated instrument accuracy. In attempting to evaluate a system accuracy by weighing mathematically the individual component errors, there is quite often the disconcerting discovery that the possible cumulative error is considerably larger than design specifications allow. With a laboratory available to test and calibrate the complete system, as a system, from primary element to final readout, there is no problem of evaluation beyond mathematical and/or physical analysis. It is no longer necessary to attempt an evaluation of instrument accuracy at half scale or quarter scale with an instrument whose accuracy is given in terms of per cent of full scale. The system accuracy determined in the laboratory may now be transferred to the operational site as much an integral part of the system as any mechanical component. Following are just a few of the many recent fluid flow problems in which the laboratory was used to advantage in finding a solution:

The design and certification of primary elements for a prototype methane liquefaction unit with pressure range 14.7 to 150 psia, temperature range 80° F to —270° F. Certified to 0.25 per cent accuracy.

The certification of a measurement system including a primary element to be used as a primary standard for the calibration of missile fuel pumps. The desired certification of 0.1 per cent accuracy was degraded to 0.15 per cent because of wide range.

The design and certification of primary elements for 2,000 psi pressure drop at 7 gpm coolant for atomic reactor component. Certification 1 per cent.

The design and certification of primary elements for missile fuel cell testing using Nitrogen, Helium, 300 psig to atmosphere with time being critical factor. Certification 1 per cent.

The calibration and certification of primary standards for use by a military agency to be used in existing laboratory installations. Periodic recalibrations are to be made of these units in an effort to detect deterioration of accuracy before it becomes a critical factor.

Among the laboratory research projects scheduled for the coming year are several which will investigate further the mechanics of even smaller rates of flow. The need continues for instruments to meter accurately flow rates of the order of 0.01 to 0.1 scfh in such gases as Oxygen, Helium, Hydrogen, and as low as 50 cc per hour of liquids of highly varying viscosities. The orifice metering of emulsions, slurries and colloidal solutions is also scheduled for investigation. Successful tests establishing the repeatability of measurement using capillary tubing of 0.006″ I. D. have already been accomplished although the predictability of such a device is still somewhat erratic. With a laboratory available for testing purposes, a first approximation may always be made with a trial-and-error method used to refine accuracies to the desired degree.

* Filban, T. J. and Griffin, W. A. "Small-Diameter-Orifice Metering," ASME Paper No. 59-A-101.

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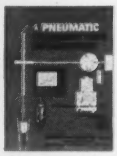
New "position-balance" type Transmitter . . . air-signals fluid rates of flow to remote recorders, controllers . . . incorporates *exclusive* calibration adjustments (no cams) and drag-eliminating magnet design . . . scale suitable for any calibration . . . offers other features of real value all detailed in new Bulletin 18N. Write for a copy.



Schutte and Koerting COMPANY
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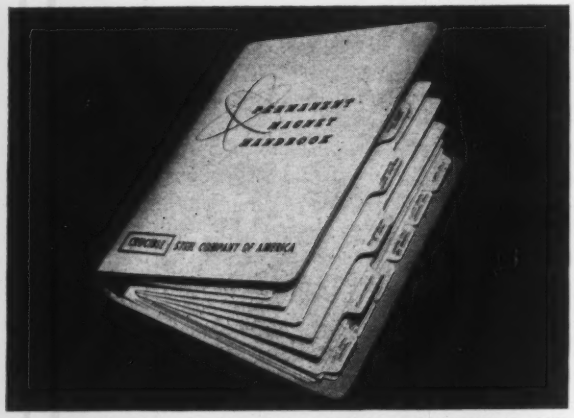
CIRCLE 73 ON READER-SERVICE CARD



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CIRCLE 74 ON READER-SERVICE CARD

Process Control Systems

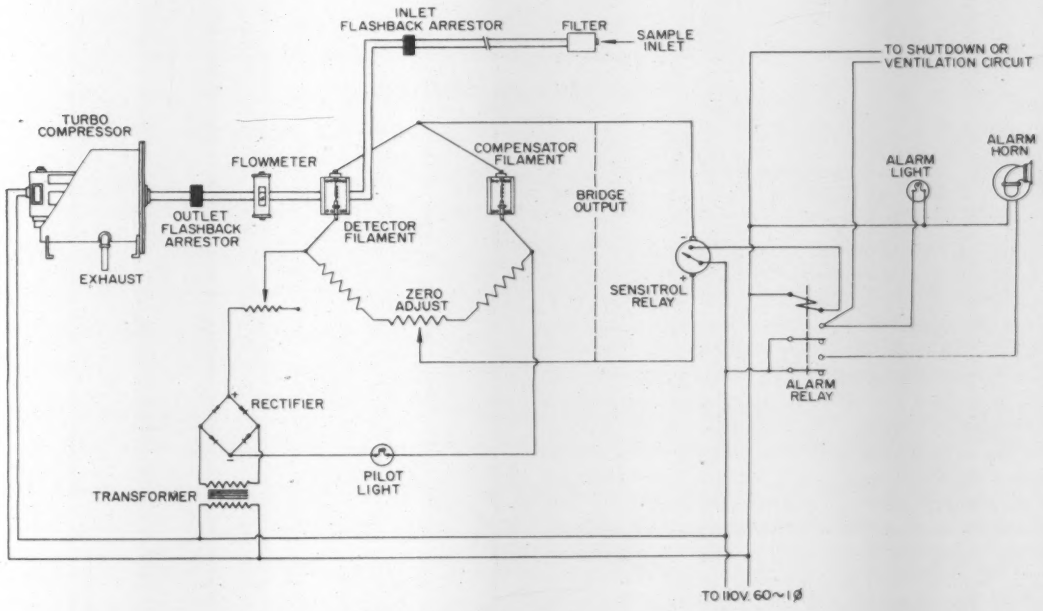
FRED D. MARTON, Instruments Publishing Company

CONTINUOUS ANALYZER MONITORS COMBUSTIBLE GASES

Detection of flammable gases is an important function in the manufacture of paint and pharmaceuticals, in stations where manufactured or natural gas is used or processed, in sewage disposal plants, in hydrogenation plants, or where gasoline is used and may be spilled, etc.

A five-stage turbo compressor is used in this system to draw a sample through an analyzer. A by-pass manifold-and-valve assembly around the analyzer is standard to permit large flow of sample. The excess of the monitored gas is by-passed directly to the pump.

The analyzer contains an integral rotameter-type flowmeter to show that the proper rate of sample flow is being maintained through the filament chamber, where a catalytically activated platinum filament induces combustion considerably below the normal ignition temperature of the combustible gas. The filament is one arm of a bridge. A compensator (reference) filament is another arm of the bridge. The electrical resistance of the detector filament increases when its temperature is increased by the combustion. The resulting unbalance in the bridge actuates a relay, which can be calibrated in percent of lower explosive limits. The bridge output also can be recorded. The relay can operate a warning signal whenever the concentration of the combustibles in a sample reaches a predetermined limit. The relays can be an integral part of the analyzer or an accessory. A ventilating fan can be energized to clear the area of residue gases, or other control or shut-down equipment can be actuated.



Equipment used: Explosive-proof combustible gas alarm, Type EX-S; potentiometer recorder (any reputable make); alarms; accessories.

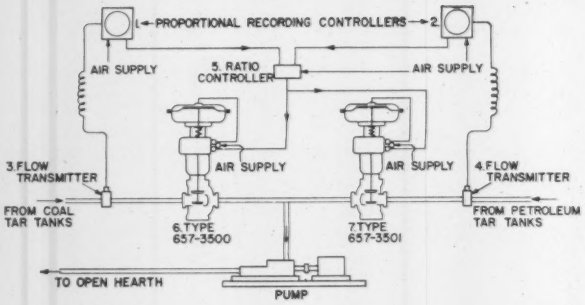
Source: Mine Safety Appliances Company, Pittsburgh, Pa.; also Bulletin 0703-3.

OPEN-HEARTH FUEL-BLENDING SYSTEM

Open-hearth operation generally uses more than one fuel. Heat transmission from the fuel to the charge undergoes a change as the process progresses and, toward the end of the process, transmission of heat by convection has practically ceased due to the slag layer which covers the bath. Radiant heat transmission then is required to keep the process going.

It is well known that a very luminous flame has good radiant heat properties. Coal tar, a readily accessible by-product in steel makings, burns with a luminous flame. However, it is not available in sufficient quantities. Thus, petroleum tar, from an outside source, has to be blended with the available coal tar to obtain ample quantities of fuel.

Due to different levels in the storage tanks the inlet pressures at the control valves (to which the fuels flow by gravity) can vary from a minimum of 2 psig to a maximum of 10 psig. The flow transmitters measure the flow through each control valve and transmit this value to the proportional recording controllers. The output from these controllers goes to the ratio controller where the two signals are balanced against each other in a predetermined ratio. The ratio controller's output is then fed to the control valves through Type 3500 valve positioners, operating on split range. One positioner is direct acting and the other one is reverse



acting. At 9-psig pressure signal from the ratio controller, both valves are wide open. At any other pressure from the ratio controller, one control valve remains wide open and the other valve throttles the flow to maintain the proper blend of the fuel.

Equipment used: Ratio controller (any make); two recording controllers (any make); two flow transmitters (any make); Fisher Type 657-A-3500 control valve with direct acting Positrol valve positioner; Fisher Type 657-A-3500 costrol valve with reverse acting Positrol valve positioner.

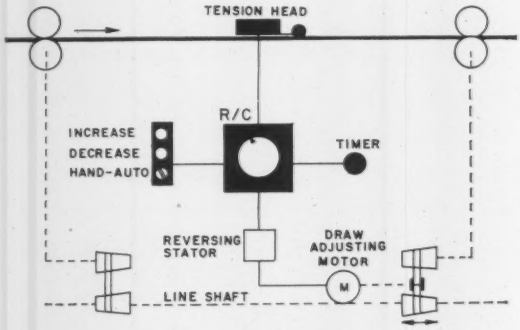
Source: Fisher Governor Company, Marshalltown, Iowa; also Application Bulletin Form AB-404.

PAPER TENSION CONTROL

In the circuit shown, a tension head (top) rides on the moving sheet, imparting a slight dimple to it. Changes in the paper tension change the roller deflection a fraction of an inch. This changes the air gap of a magnetic structure which emits an electrical signal proportional to tension. A recorder measures the output of the tension head and records the value on an arbitrary 0-to-100 scale. It can be calibrated by the user in absolute units such as lb/in. Control is provided in setting high and low limits of tension by adjustable switches on the draw-adjust mechanism. When the limits are exceeded, a motor is energized through a reversing starter. The motor actuates a speed changer such as a belt drive on conical pulleys, a system which is primarily used on lineshaft-driven paper machines.

As the motor speed is usually too fast for automatic control, a timer with a preselected fixed time cycle turns off the motor for a waiting period before a further correction is made. A third switch in the controller cuts out the control circuit if a break in the web occurs. It can simultaneously actuate an alarm. A pushbutton station provides manual and/or automatic control.

In the paper-making process an important control function is to keep the proper tension on the stock passing through the paper machine. As the material changes its moisture content from the wet end until it approaches the final stage and becomes a dry product, the tension, naturally, can be increased.



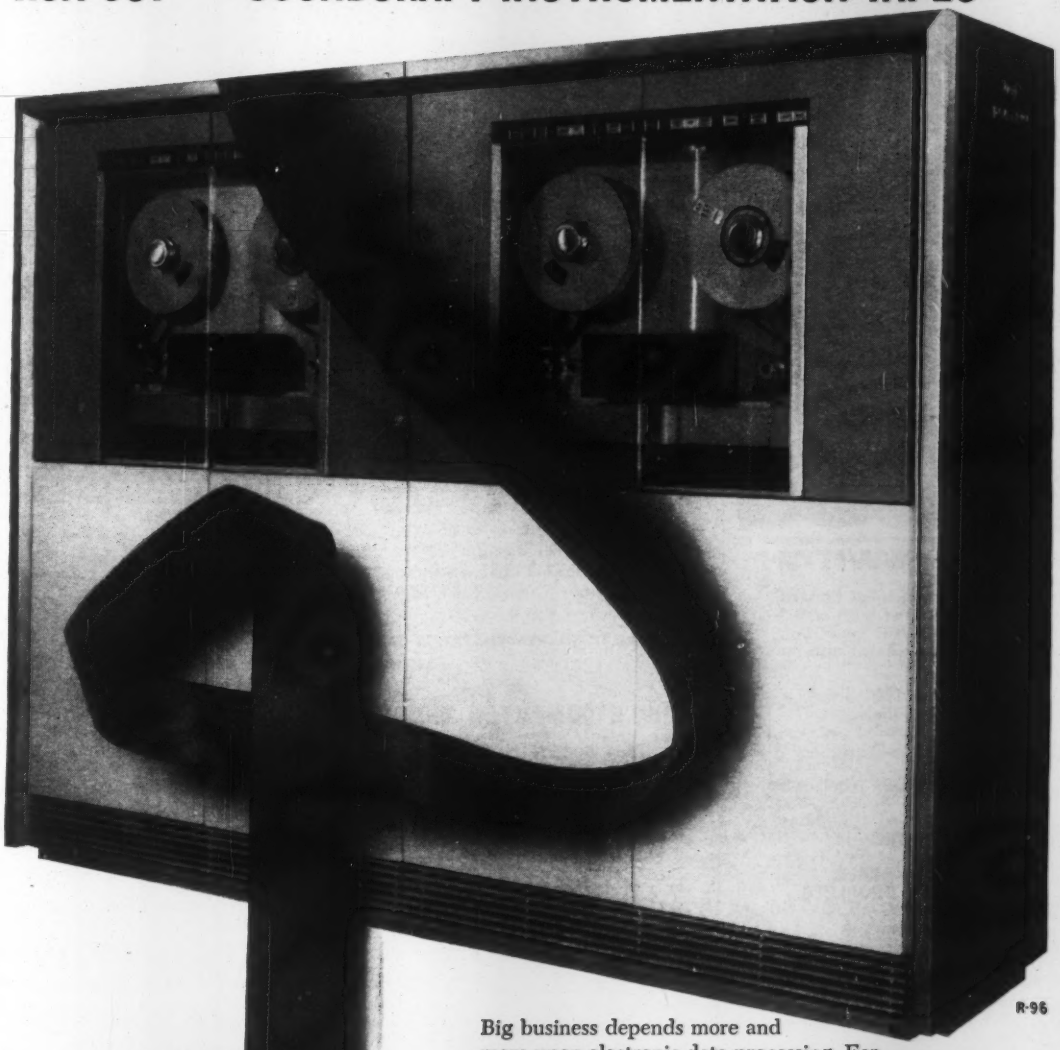
Tension control is exercised at various sections of a paper machine. Factors affecting the tension at the wet end are stock freeness, stock consistency, vacuum in suction boxes, condition and cleanliness of press felts, etc. They have a definite effect on the moisture content of the sheet and thus on the tension at the dry end.

Equipment used: Tension head; potentiometer recording-controller, Type HR (round chart) or Type HF (strip chart); timer Type TSA-14; pushbutton station with manual/automatic switch.

Source: General Electric Company; also Product and Application Information GET-2741-7A.

WORKING PARTNERS

RCA 501 — SOUNDCRAFT INSTRUMENTATION TAPES



R-96

Big business depends more and more upon electronic data processing. For many corporations, the heart of their data reduction and storage operation will be the new RCA 501 Computer System. The crucial testing period of this new computer called for the most reliable of instrumentation tapes . . . Soundcraft. And, Soundcraft Tape proved to be the perfect working partner—not only in the testing, but afterward, in continuous working use.

In short, experience has proven that Soundcraft works best on leading computer systems, like the RCA 501. Let precision-made, trouble-free, error-free Soundcraft Instrumentation Tapes go to work for you. *Complete literature on request.*

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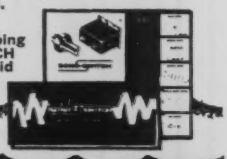
Write today for literature describing how SONOSWITCH can help your fluid control problem.



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CIRCLE 76 ON READER-SERVICE CARD

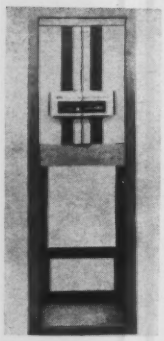
ICS NEW INSTRUMENTS

PROGRAMMERS

New modular, 85-channel Programmers are available with punch card or punch tape. Punched Card Programmer uses 5″ x 9″ vinyl cards, brush-wipe circuit. Card carriage resets at any position to 30 steps. Punched Tape Programmer uses 9″ tape, 64 steps/ft. Tape returns to any program point or to re-cycle. Accessory banks of memory type load relays and Dual Timer optional.—*Industrial Timer Corp.*, 1407 *McCarter Highway, Newark* 4, *N. J.*

CIRCLE 221 ON READER-SERVICE CARD

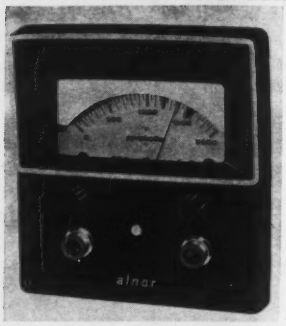
MOBILE COMPUTER MONITOR



New data-acquisition and computting system incorporates battery-operated PB250 digital computer, provides on site data-processing capabilities not previously available in mobile equipment. System accepts analog data from up to 60 sources, converts data to digital form, records information on magnetic tape. System energizes alarms, makes logical decsions, and provides information for logging typewriter or paper tape punch.—*Packard Bell Computer, Subs. Packard Bell Electronics*, 1905 *Armacost Ave., Los Angeles* 25, *Calif.*

CIRCLE 222 ON READER-SERVICE CARD

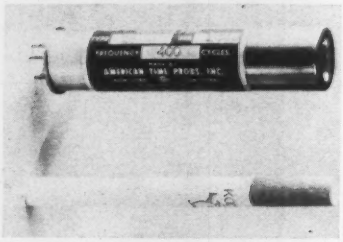
INDICATOR-CONTROLLER



New double-target temperature indicating-controlling pyrometer, N-15 Pyrotroller, controls temp and provides second control point for secondary action (opens and closes valve, turns motor or blower on and off, etc.) Available in 11 ranges from 0°-400°F to 0°-3000°F.—*Alnor Instrument Co.*, 418 *N. LaSalle St., Chicago* 10, *Ill.*

CIRCLE 223 ON READER-SERVICE CARD

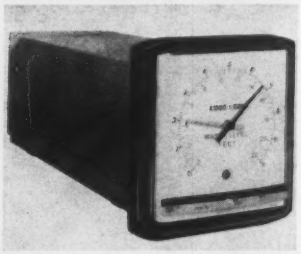
FORK OSCILLATING UNIT



New precision Fork Oscillating Unit is of bi-metal construction, hermetically sealed; ⅝″ x 2 $\frac{9}{16}$″, weighs 2 oz; 7-prong base. Stock frequencies 400 and 500 cycles; available from 200 to 1000 cycles. Type 25T is for use with germanium or silicon transistor circuit; Type 25V is for use with double triode: tolerances of ±0.02% from −65° to 85°C.—*American Time Products, Inc.*, 61-20 *Woodside Ave., Woodside* 77, *N. Y.*

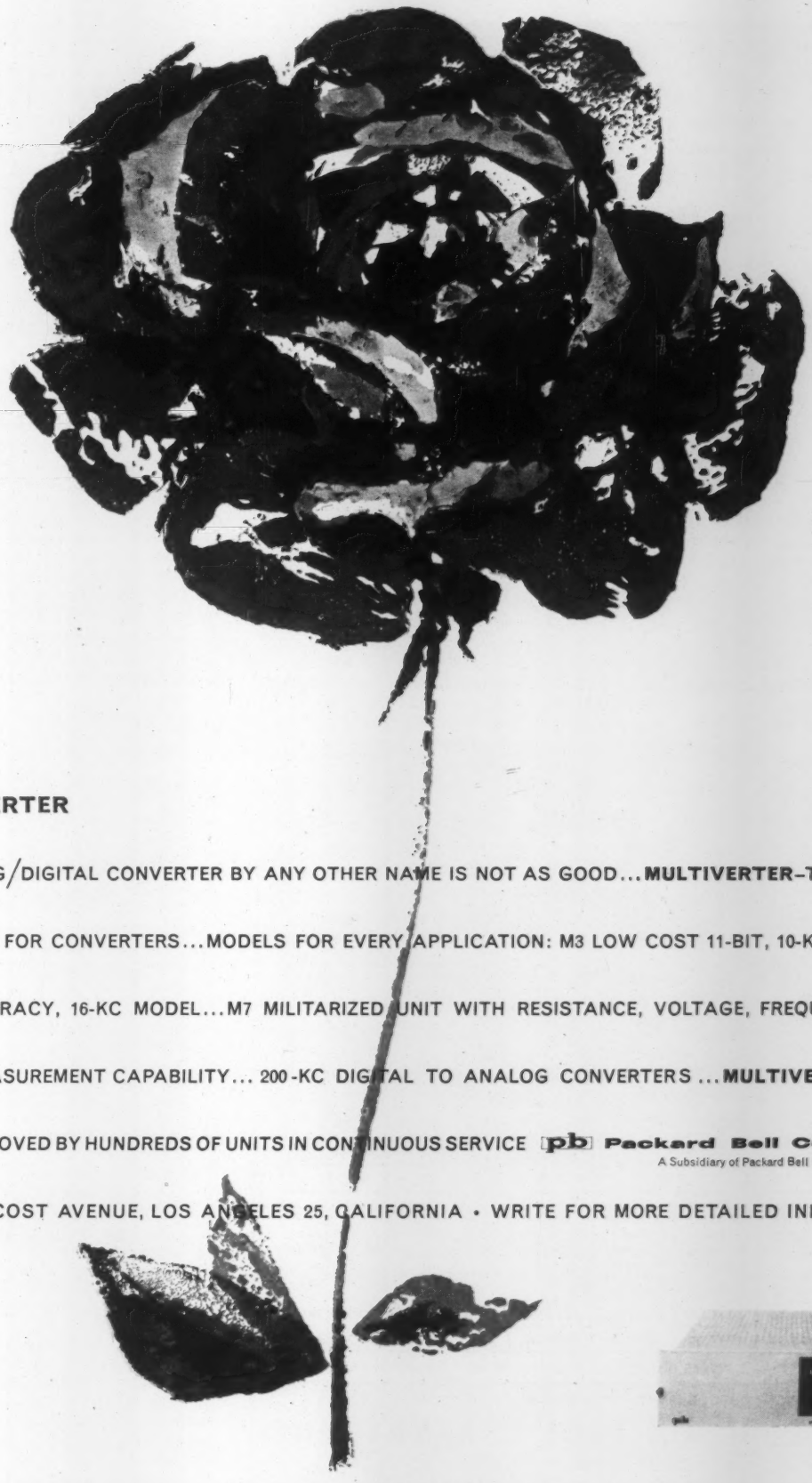
CIRCLE 224 ON READER-SERVICE CARD

TELEMETERING RECEIVERS



New Single-Function Indicator, Dual-Function Indicator (shown), Indicator/Totalizer, and Panel-Mounted Totalizer never need lubrication, have large, clear graduations and numerals for easy reading, have low-voltage transmission system with transistor switches.—*B-I-F Industries, Inc., Providence* 1, *R. I.*

CIRCLE 225 ON READER-SERVICE CARD



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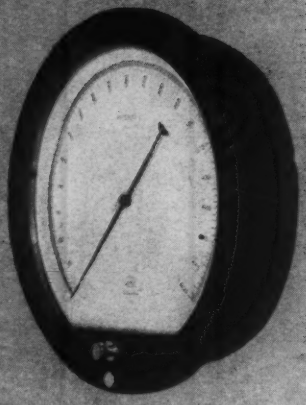
CIRCLE 77 ON READER-SERVICE CARD

HEISE GAUGES

Test Standard ACCURACY



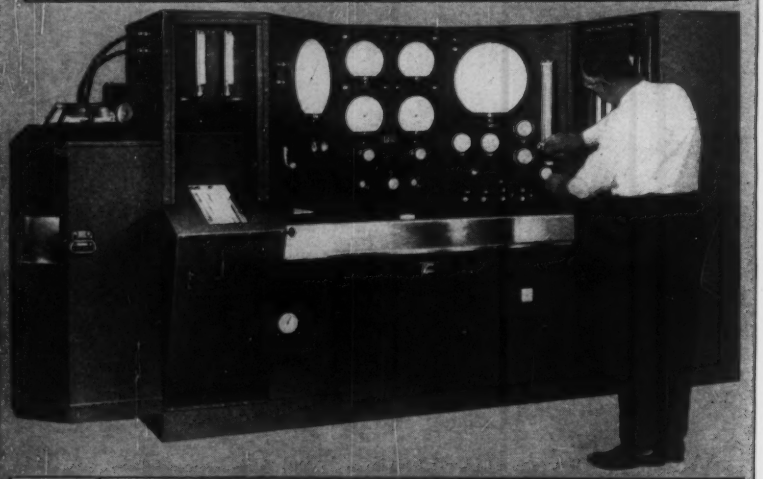
Only Heise gauge guarantees accuracy to 0.1 of 1% full scale reading at all points on a fully graduated 270° dial.

In laboratories throughout the world, the Heise gauge is being used as a test reference for recalibration of other instruments and testing of critical components.

All Heise gauges maintain the same standard of accuracy and are available in ranges from 0 to 15 p.s.i. to 0 to 100,000 p.s.i. Hysteresis, regardless of pressure range, is held within the same 0.1 of 1%.

The Heise laboratories, specialists in Bourdon tube equipment since 1930, have developed and perfected this instrument which stands alone in the field as a secondary standard approached only by the primary dead weight tester.

ACCURACY	HYSTERESIS	CAPACITY
0.1 of 1%	0.1 of 1%	0-100,000 p.s.i.



Dial Sizes	FULL SCALE READING (P.S.I.)						
	0-15 to 0-5,000 inclusive	Over 0-5,000 and including 0-20,000	Over 0-20,000 and including 0-30,000	0 to 40,000	0 to 50,000	0 to 75,000	0 to 100,000
8½"	$183.50	$205.50	$238.50				
12"	$209.50	$231.50	$264.50	$275.50	$286.50	$336.50	$386.50
16"	$255.50	$277.50	$310.50	$321.50	$332.50	$382.50	$432.50

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CIRCLE 78 ON READER-SERVICE CARD

SERVO VALVE TEST STAND

New Model 2784 Servo Valve Test Stand automatically records in X-Y form combinations of flow, piston force, pressure, and displacement. Motor-driven spool displacement device has linear position accuracy of 0.0001". Flow system accuracy is ±¼ of 1% of instantaneous reading. Flow, 5 cc/min to 1,000 gpm; force, 0.1 gm to 5 tons; displacement, 0.0001" increments to any amplitude; pressures to 5000 psig.—*Auto-Control Labs. Inc., 5251 W. Imperial Highway, Los Angeles 45, Calif.*

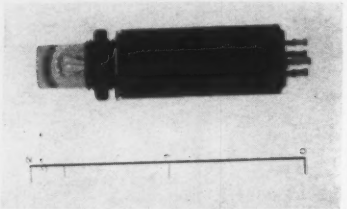
CIRCLE 226 ON READER-SERVICE CARD

COMPRESSOR/VACUUM PUMP

New 1/12-hp oil-less Compressor and Vacuum Pump operates at 1725 rpm with split-phase, induction-type motors. Model LV has 1.9-cfm displacement, operates contiuously to 27" vacuum; Model LC has 1.43-cfm displacement, operates continuously to 65 psig.—*Bell & Gossett Co., Morton Grove, Ill.*

CIRCLE 227 ON READER-SERVICE CARD

FLIP-FLOP WITH MEMO LIGHT



New Model DS-1000 Flip-Flop features built-in MEMO incandescent indicator light, switches 2 μsec pulse with 1-ma input.—*C & K Components, Inc., 103 Morse St., Newton 58, Mass.*

CIRCLE 228 ON READER-SERVICE CARD

REMEMBER COLLAR BUTTONS?

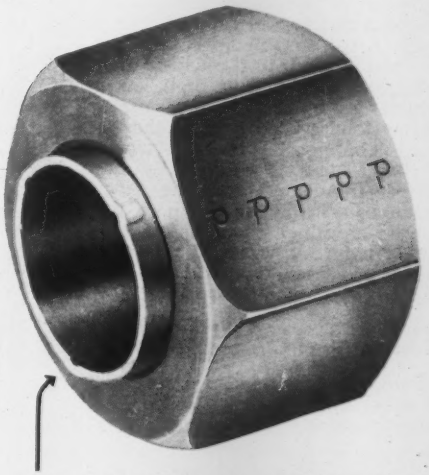
NOW **PARKER** HAS ELIMINATED A MORE SERIOUS ANNOYANCE ...LOST TUBE FITTING FERRULES!

A simple change in the design of Parker "Intru-lok®," the positive, bite-type Parker fitting for copper, aluminum or plastic tubing, has solved an age-old problem.

Small three- and four-piece tube fittings have long been a pain in the neck on applications where it is necessary to remove the nut from the fitting. The ferrule(s) fall out and promptly disappear. If and when found, they often get put in backwards. Sometimes they never get put back at all. Result, in either case: a leaking joint.

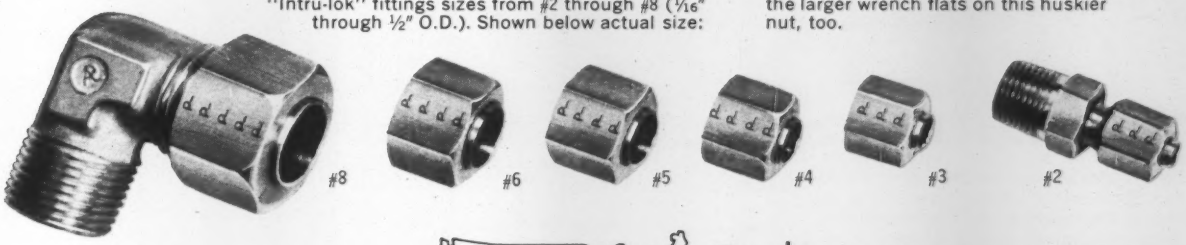
Now Parker has developed a snap-in, captive ferrule for "Intru-lok." You can take it out of the nut, "on purpose," but you can't drop it out accidentally.

You get all the leakproof safety of a three-piece fitting with positive "bite." You also get the convenience, the quick, easy assembly of a two-piece fitting. The easiest fitting to install has been made even easier. Write for new "Intru-lok" dimensions and prices today.



Three "detents" hold the "tail" of the new ferrule in the nut. Also, the larger hole in the nut makes tube bends closer to the fitting possible. Note the larger wrench flats on this huskier nut, too.

The new nut with captive ferrule is available on all "Intru-lok" fittings sizes from #2 through #8 (1/16" through 1/2" O.D.). Shown below actual size:



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CIRCLE 79 ON READER-SERVICE CARD

D-C AMPLIFIER EVALUATION *number 2 in a series*

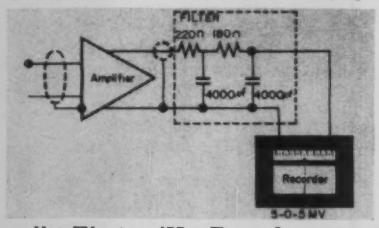
ZERO DRIFT

Accuracy in d-c amplifiers is fundamentally dependent on zero drift. This error, defined as any zero offset appearing at the amplifier output but not present in the input, is indistinguishable from the d-c input signal, and varies more or less sporadically with time and/or ambient temperature. Elimination of zero drift is a prime d-c amplifier design objective.

Evaluation of the amplifier zero drift characteristic is quite simple, but elimination of the effect is not. For example, any direct-coupled stage of amplification will drift due to the inability of circuit operating levels to remain constant. The use of inverse feedback does not have any beneficial effect on drift. The best generally accepted method of drift elimination is to make all amplification drift-free through a-c coupling, and converting the incoming d-c to a-c directly by means of a low-level modulator, such as a chopper or magnetic converter. After amplification, the a-c is demodulated into d-c which may be further amplified at high levels without appreciable zero error. This system is used in both the so-called chopper amplifier (where the band pass is limited by the chopper frequency) and the chopper-stabilized amplifier (where the chopper amplifier is combined with a wide band amplifier to give frequency responses well beyond the chopper excitation frequency).

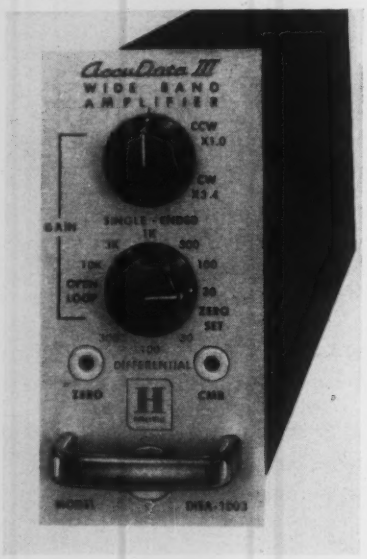
Testing Amplifiers for Zero Drift

Zero drift is measured at the amplifier output with a strip chart potentiometer such as the Honeywell ElectroniK Recorder connected through a low pass filter as shown. The amplifier input should be shorted. Equivalent input drift is the absolute amount recorded at the output divided by the amplifier gain measured under known conditions of temperature and line voltage, and, if necessary, for a specified time. There do not seem to be agreed-upon definitions of short or long-term time periods. For further details, write for Bulletin BE AN122.



Zero Drift Less Than 0.02 Per Cent at 10 mv

The AccuData III, Honeywell's all-transistor, wide-band, differential input, chopper-stabilized, d-c amplifier, has the lowest drift of any amplifier in its field — something less than 0.5 microvolts at reasonably constant ambient temperature, or less than 2 μv with a 10°F change in ambient. The effect of line voltage never exceeds 1 μv for a $\pm 10\%$ change, hence, under conditions most frequently advertised for amplifiers, its zero error with a 10mv input signal would be less than 0.02%.



The AccuData III has single-ended as well as differential input ranges, input impedance of 2 megohms differential (20 megohms single-ended), and power output sufficient to drive the highest frequency galvanometer oscillograph to its maximum deflection. In addition to excellent drift characteristics, the AccuData III offers exceptional linearity, very low noise, and frequency response to 20kc. Write for Bulletin BS-DISA-3 to Minneapolis-Honeywell, Boston Division, Dept. 50, 40 Life Street, Boston 35, Mass.

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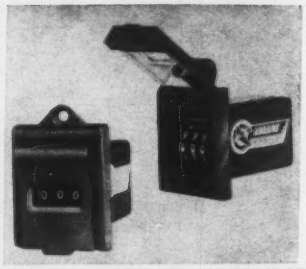
CIRCLE 80 ON READER-SERVICE CARD

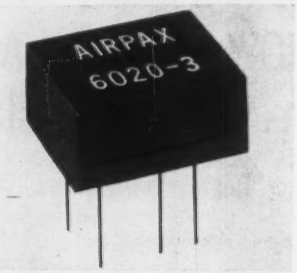
LIGHTED COUNTER



New 1⅛" x 2" x 2⅝" Model CE-L 3-figured magnetic Counter has light in cover to illuminate counter wheels, is available in either additive or subtractive version for 6, 12, 24, and 110 v dc. Records up to 20 pulses/sec. Operates from −65° to 160°F; 25 foot lamberts min at 28v light intensity; 1,000,000 counts, min life.—*Abrams Instrument Corp., 606 E. Shiawassee St., Lansing 1, Mich.*

CIRCLE 229 ON READER-SERVICE CARD

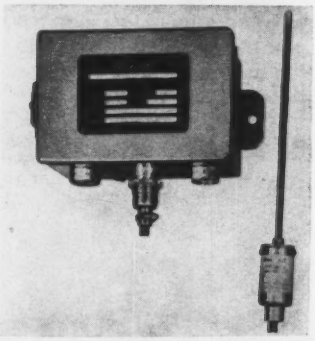
PRINTED CIRCUIT CHOPPER



New molded transistor Chopper, Type 6020-3, operates over dc to 100-kc chopping range, −55° to +125°C. Drive voltage 2-20 v peak square wave or 5-20 v peak sine wave.—*Airpax Electronics Inc., Cambridge Div., Cambridge, Md.*

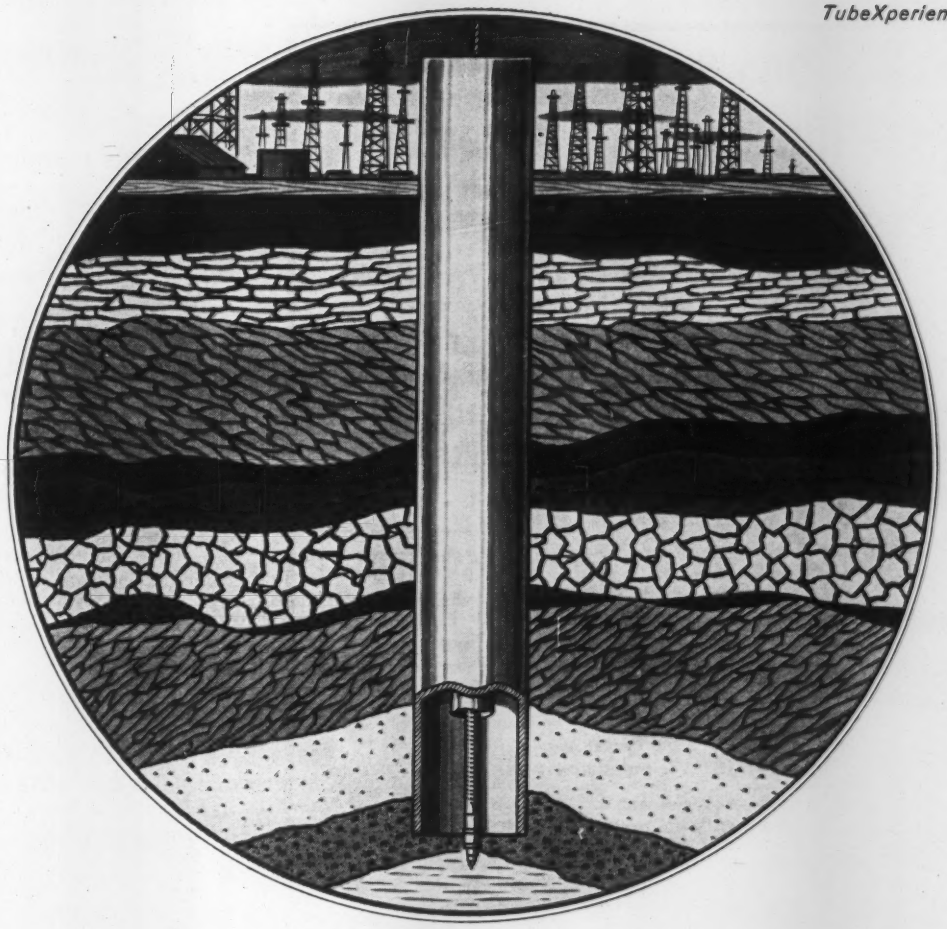
CIRCLE 230 ON READER-SERVICE CARD

AIR FLOW TRANSDUCER



New air velocity transducer system combines precise air flow sensing element with read-out system that retains sensing element accuracy. Available in models for deflection-type indicator read-outs or potentiometric read-outs, operates in air temps from 20° to 150°F.—*Alnor Instrument Co., 420 N. LaSalle St., Chicago 10, Ill.*

CIRCLE 231 ON READER-SERVICE CARD



Deep well pressure readings within .05% accuracy with help of Superior Ni-Span C* Bourdon Tubing

Accurate down-well pressure readings, indicating changes of only 1 to 4 psi at bottom-hole pressure of 2000 psi, are hard to get, but extremely important. They demand a pressure gage accuracy of at least 0.1% to make the vital engineering calculations based on them of any value.

To achieve this accuracy and better it, Superior was asked for help in selecting the Bourdon tube material for an improved bottom-hole measuring device. After careful study, its metallurgists recommended Ni-Span C nickel-chrome alloy for the Bourdon tubes. This material was chosen for its relative insensitivity to temperature changes, coupled with superiority in operating temperature, mechanical hysteresis, and elastic drift; also for its fatigue resistance and spring properties.

The customer followed the suggestion and now this gage, which is unique in bottom-hole pressure instruments for the reason that it utilizes a helix-wound Bourdon tube to transmit directly the effects of pressure to a recording stylus, is rated 0.1% accurate. In fact, with special care in operations and calibration, it can measure within .05% accuracy.

NI-SPAN C TUBING NOW STANDARD AT SUPERIOR

Ni-Span C redraw stock is now in inventory at Superior, available for immediate production in a range of sizes from .010 in. to ⅝ in. OD, up to .125 in. wall max., and from ⅝ in. to 1⅛ in. OD in wall thicknesses up to .035 in. max. Shaped tubing can be produced to customers' prints. Perhaps you have an application that can benefit from its unusual properties. Write for Data Memorandum No. 19. Superior Tube Company, 1968 Germantown Ave., Norristown, Pa.

*Registered trademark of International Nickel Co.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

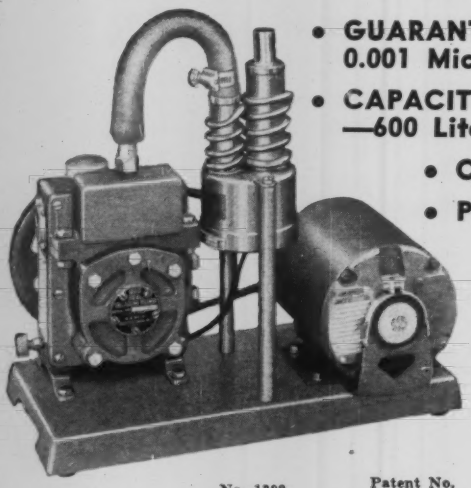
All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

CIRCLE 81 ON READER-SERVICE CARD

Welch Duo-Seal® Mechanical and Diffusion Pump Assembly

EACH ELEMENT WITH TWO-STAGE CONSTRUCTION
WATER-COOLED OR AIR-COOLED MODELS



- **GUARANTEED VACUUM— 0.001 Micron** (0.000 001 mm Hg)
- **CAPACITY AT 0.1 MICRON —600 Liters Per Minute**
- **CONVENIENT**
- **PORTABLE**

$300.00 Complete with Motor

No. 1392 Patent No. 2337849

1392. MECHANICAL AND DIFFUSION PUMP, Water-Cooled
For 115 Volts, 60 Cycles, A.C. Each, $300.00

1392A. MECHANICAL AND DIFFUSION PUMP, Air Cooled.
For 115 Volts, 60 Cycles, A.C. Each, $300.00

For attached Belt Guard, add $15.00 to above prices.

1391. DIFFUSION PUMP, Only, Water Cooled, With Octoil. Each, $160.00

1394. DIFFUSION PUMP, Only, Air Cooled With Octoil. Each, $160.00

1393. MOUNTING PARTS.
For mounting No. 1391 or No. 1394 Diffusion Pump on base of mechanical pump. Set, $3.00

Other combinations are available with speeds of up to 16,500 liters per min at 0.1 micron. We will gladly submit full details describing the best combination for your particular application.

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ESTABLISHED 1880
1515 Sedgwick Street, Dept. B Chicago 10, Illinois, U.S.A.
Manufacturers of Scientific Instruments and Laboratory Apparatus

CIRCLE 82 ON READER-SERVICE CARD

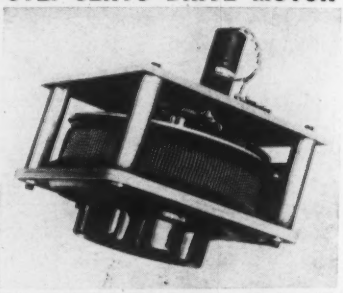
Over 40,000 copies of the 1962

ICS' BUYERS GUIDE

will be distributed to instrument and control equipment and component users. Publication date—October 1961. Be sure your products are represented with complete data in Catalog Ads and free listings. Contact any of our reps, listed on page 172—or write ICS' Buyers Guide, 845 Ridge Ave., Pittsburgh 12, Pa.

ICS NEW INSTRUMENTS

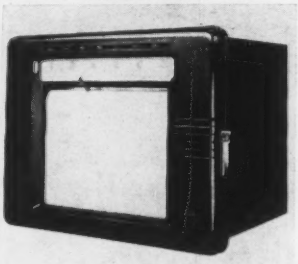
STEP-SERVO DRIVE MOTOR



New Model A604A Step-Servo Motor Drive for variable autotransformers operates with ADC Step-Servo Controllers and pulse sources, forms new tool for autotransformer control independent of line frequency. Unit actuates W20 (50-420 cps) or M20 (350-1200 cps) Variac to within 0.2° at rates to 110 increments/sec. Drive units for other variable autotransformers available.—*Automation Development Corp., 11824 W. Jefferson Blvd., Culver City, Calif.*

CIRCLE 232 ON READER-SERVICE CARD

RECORDER



New Automatic Extended Range Recorder has from 2-5 automatic steps of zero suppression, with zero automatically shifted to accommodate any signal within range from 2-250 mv. Max total span of 500 mv. Equipped with two pens. Accurate to ¼ of 1% of entire span and sensitive to 1/10 of 1% of each span.—*Barber-Colman Co., Wheelco Industrial Instruments Div., 1700 Rock St., Rockford, Ill.*

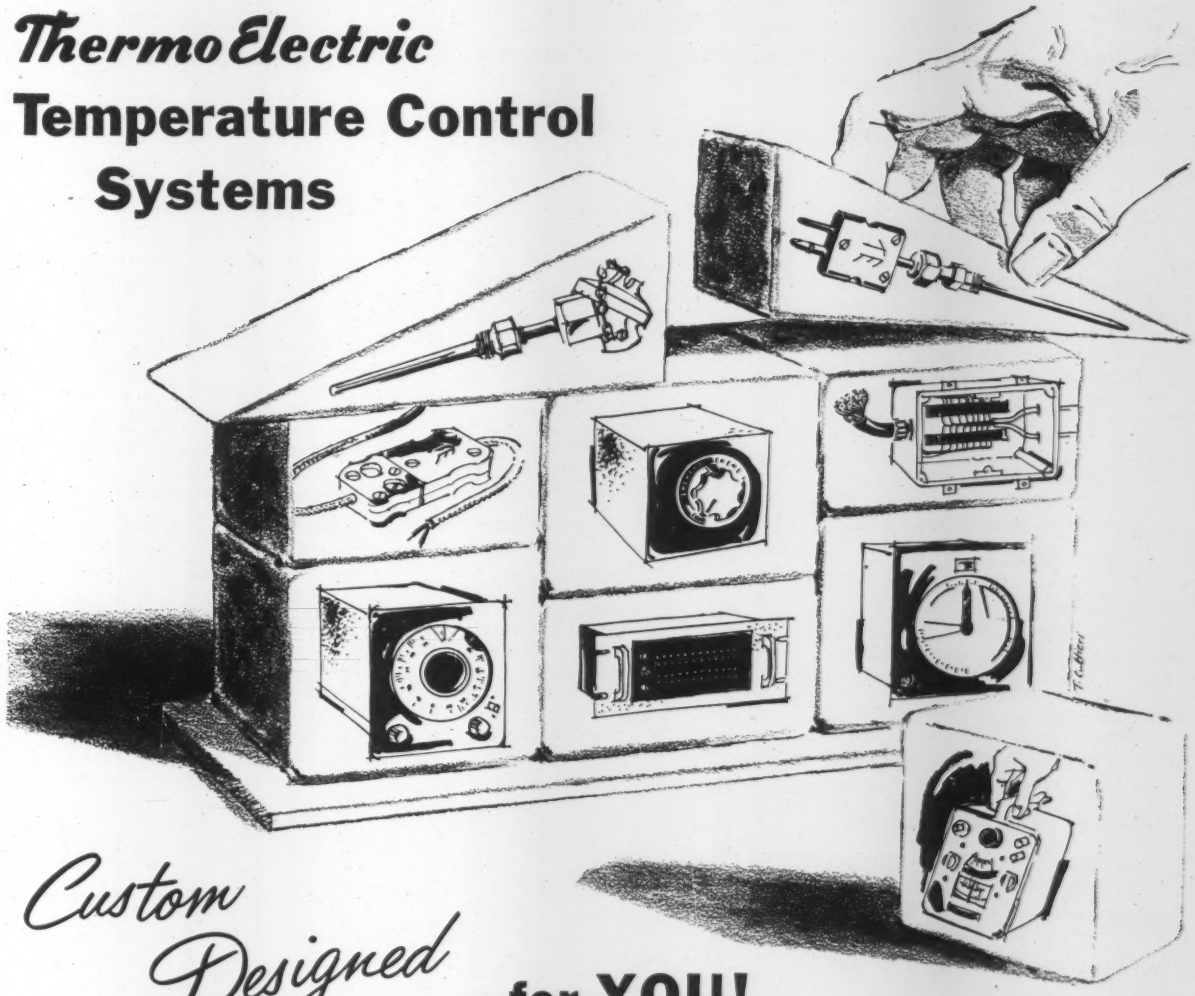
CIRCLE 233 ON READER-SERVICE CARD

DC POWER AUXILIARY

New Power Auxiliary provides stabilized voltage for operating 150-w XBO-162 Xenon Arc Lamps. Unit regulates light output within ±1% for line voltage variations as great as ±12%. Device consists of Sola Constant Wattage Transformer, step-down transformer, full-wave rectifier, capacitive filter, and relays. Bulletin XL-411.—*Sola Electric Co., Div. Basic Products Corp., Busse Rd. at Lunt, Elk Grove, Ill.*

CIRCLE 234 ON READER-SERVICE CARD

Thermo Electric Temperature Control Systems



Custom Designed — for YOU!

Thermo Electric advanced systems-building components permit custom designing to satisfy your temperature monitoring, indicating, recording, or controlling requirements, exactly and economically. Starting with T. E. thermocouples—standard or special calibrations—from 1 inch to 66 feet and longer, accessories are carefully selected by T. E. applications engineers to relay any number of signals to your instrument panel. Quick-coupling plug and jack connectors and panels, extension wire and cable are precisely matched to eliminate false emf's. Junction boxes, rotary, key or push-button selector switches are all designed and constructed by T. E. to the highest quality standards.

To monitor, indicate, record or control process variables, T. E. offers the compact Signaling Controller—the Indicating Controller and Indicating Recorder with large, easily-read scales, or special multi-point monitor systems. All instruments have front-set controls, complete in-the-field range interchangeability, ease of service, and feature the new High Gain Relay or Servo Amplifiers with high sensitivity and exceptional stability.

The portable "MiniMite" Indicator with 23″ scale and 0.25% scale accuracy, can be used to indicate on-the-spot temperature or for calibration and test work.

Let us assist in building your process control system.

Send application details on your letterhead today to Dept. 12

Thermo Electric CO., INC. SADDLE BROOK, NEW JERSEY

In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ontario

NEW INSTRUMENTS

MECHANICAL DIFFERENTIAL

New Model X-1943 Differential for loads to 75 in-oz and speeds to 3500 rpm is used in servo systems and for integrating mathematical functions in computing equipment. Backlash held to 1½ min with 0.5 in-oz checking load; starting torque 0.1 in-oz.—*Bowmar Instrument Corp.*, 8000 *Bluffton Rd., Fort Wayne, Ind.*

CIRCLE 235 ON READER-SERVICE CARD

IMPRESSION PROBES

New Model 171 Series Immersion Resistance Temperature Sensors have miniature platinum wire element fully supported and strain free. Temp range −435° to +700°F, stability 0.2°F or better, response time 0.75 sec, operating pressure to 5000 psi. For use in cryogenic fluids, corrosive fluids, fluids in high pressure processes.—*Rosemount Engineering Co.*, 4900 *W. 78 St., Minneapolis 24, Minn.*

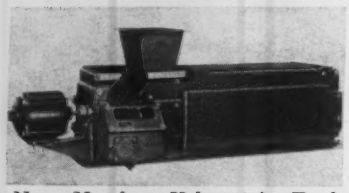
CIRCLE 236 ON READER-SERVICE CARD

COMPUTER SUPPLY

New battery power supply for solid-state PB250 Computer is continuously regenerated by trickle charging. If standard 115-v input to charger is interrupted, computer continues operation for more than 1 hr. Battery supply incorporates sealed cells which operate for over 5 years without service.—*Packard Bell Computer, Subs. Packard Bell Electronics*, 1905 *Armacost Ave., Los Angeles 25, Calif.*

CIRCLE 237 ON READER-SERVICE CARD

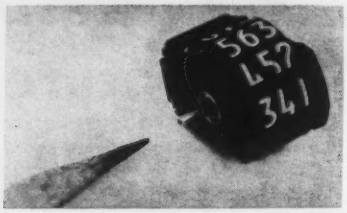
VOLUMETRIC FEEDER



New Merchen Volumetric Feeder features belt-and-feed-gate design for measuring free-flowing powdered, granular, or lumpy solids by volume. Model with 9" belt feeds from 0.1-600 cfh; 18" Model, from 0.6 to 3600 cfh. Feed rate adjustable over a 10:1 range; accuracy maintained within ±3% over any 1-min period. Belt speeds change by means of 2-speed gear box, to give 100:1 range.—*Wallace & Tiernan Inc.*, 25 *Main St., Belleville 9, N. J.*

CIRCLE 238 ON READER-SERVICE CARD

PRECISION COUNTERS



New Series 1736 internal pinion Counters provide 0.220" figure in 0.305" opening for improved readability in below-eye-level instruments. Static torque of 1.00 oz-in from −55° to 100°C. Available with 3- or 4-figure wheels, as well as plate extensions with 2 stationary zeros and decimal point indication; also left wheel stops. Speed, 750 rpm intermittent and 300 rpm continuous.—*Veeder-Root Inc.*, 70 *Sargeant St., Hartford 2, Conn.*

CIRCLE 239 ON READER-SERVICE CARD

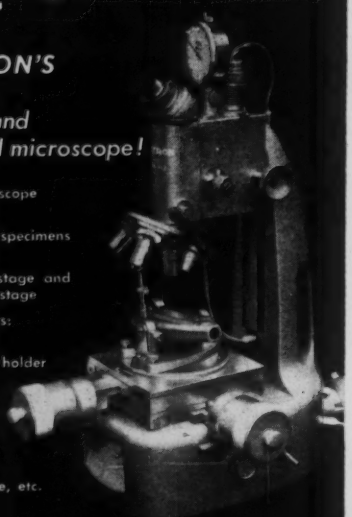
PRECISION BALANCE

New Model L Precision Balance has double hook design, weighs as low as 0-3 mg or as high as 0-50 gm. By counterweighing, handles loads up to 3 times scale value. Accurate to ±0.1%. Lock and release lever; magnetic damping system; verneir index reads to 1/10 scale division.—*Federal Pacific Electric Co.*, 50 *Ave. L, Newark 1, N. J.*

CIRCLE 240 ON READER-SERVICE CARD

MEASURE IN 3 DIMENSIONS TO 0.0001"

with UNITRON'S Combination Toolmakers and Metallurgical microscope!



- Direct reading from microscope screws and dial indicator
- Examines polished metal specimens at 30X, 100X, 400X, etc.
- Ball bearing rectangular stage and calibrated circular rotary stage
- Three separate illuminators: substage, surface, vertical
- Inclinable work and tool holder
- Accessories include viewing screen for contour projection and optical comparison, eyepiece scales for measuring screw threads, diameters, metal grain size, etc.

Even the smallest shop can rapidly pay for this versatile instrument in time and materials saved. UNITRON Model TM, with all its features, costs about the same as the lowest priced, simple shop microscope. .....fob Boston only $1050

Write for Bulletin TM 22-L

UNITRON INSTRUMENT COMPANY • MICROSCOPE SALES DIV 66 NEEDHAM ST., NEWTON HIGHLANDS 61, MASS.

CIRCLE 83 ON READER-SERVICE CARD

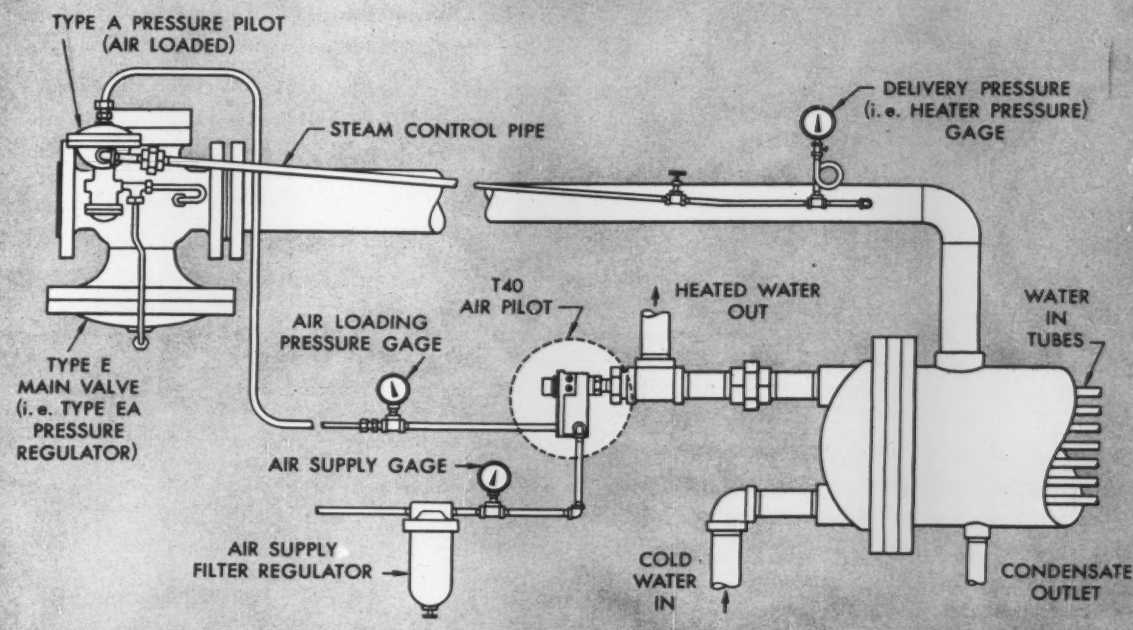
2 important ad-readership survey issues . . .

MARCH AUGUST

John T. Fosdick Associates will conduct, among **Instruments & Control Systems** readers, a Study of Advertising and Editorial Readership. The resultant performance ratings are related to the readers job function, for heightened significance.

Be sure to advertise in these special Study Issues. Contact any of ICS' reps, listed on page 172—or write, wire, or call **Instruments & Control Systems**, 845 Ridge Ave., Pittsburgh 12, Pa. FAirfax 1-0161.

New Spence Temperature Control System with Cascade Control Accuracy at Regulator Costs


TYPE A PRESSURE PILOT (AIR LOADED)
STEAM CONTROL PIPE
DELIVERY PRESSURE (i.e. HEATER PRESSURE) GAGE
T40 AIR PILOT
HEATED WATER OUT
WATER IN TUBES
AIR LOADING PRESSURE GAGE
TYPE E MAIN VALVE (i.e. TYPE EA PRESSURE REGULATOR)
AIR SUPPLY GAGE
AIR SUPPLY FILTER REGULATOR
COLD WATER IN
CONDENSATE OUTLET

TYPE EAT40 AIR-CONTROL TEMPERATURE REGULATOR (Patent Pending)

In a recent installation the new Spence air-control temperature regulating system provided:

- ±5°F control accuracy under wide and instantaneous load swings of 210 to 80 gallons per minute.
- Up to 50% reduction in cost as compared to instrument systems of similar accuracy.

This unique cascade-type control with throttling range adjustment independent of maximum heater pressure was developed to meet today's demand for greater control accuracy.

Additional features of the new Spence Temperature Control System include:

- 200°F wide adjustable temperature range
- Adjustable speed of steam pressure change
- Over and under temperature protection
- Pressure limit control
- Fast response
- Very low air consumption
- Field reversible for heating or cooling

The Spence Type EAT Air Control Temperature System, when properly installed, will tame wide ranging, fast changing loads of instantaneous heaters and modern heat exchangers. The cascade principle plus the use of an extremely fast responding bi-metal temperature sensing element reduce time lags and provide control stability.

Here's how the new Spence system operates:

Quick response is based on a bi-metal temperature sensing element.

Temperature pilot continuously regulates a loading air pressure.

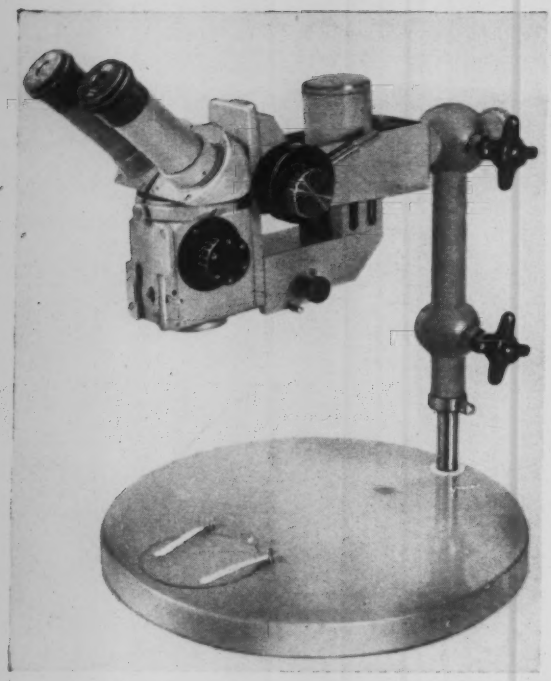
This loading signal, when applied to a pressure regulator to reflect heater temperatures, causes it to adjust the main valve as changes in load require.

Spence has also developed a new pressure control system based on this same cascade principle. This system has a control accuracy of ½ psi or better from positive pressures through the vacuum range to 30" Hg.

For complete information on these new air controlled temperature and pressure control systems, write for your copy of Bulletin 9.

SPENCE ENGINEERING COMPANY, INC.
Walden, New York 9E-148A

CIRCLE 84 ON READER-SERVICE CARD



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MADE IN WEST GERMANY

A modern stereoscopic binocular microscope eminently suited for industrial inspections and examinations.

Intense illumination parallel with line of vision. Erect, plastic image even in deep cavities.

Free working distance of 8 inches. Magnification changing device provides rapid succession of 6.3x, 10x, 16x, 25x and 40x magnifications.

Write for free detailed literature.

CARL ZEISS, INC.

COMPLETE SERVICE FACILITIES

485 FIFTH AVENUE, NEW YORK 17, N. Y.

CIRCLE 85 ON READER-SERVICE CARD

3 new instruments for process control

MV-1 POTENTIOMETER

For testing, calibrating or servicing newest process controllers and amplifiers which convert millivolt input signals into proportional currents for control or telemetering. Combines all functions of precision potentiometer, millivolt source and milliammeter. 1/10 of 1% accuracy. 5⅜″ x 8″ x 5⁹⁄₁₆″. 5½ lbs.

THE AUTOCOMP 1

For instrument checking and thermocouple measuring. Gives automatic cold junction compensation to devices used for measuring or controlling with thermocouples. Exclusive circuit employs thermistor network to match non-linear characteristics of thermocouples with output characteristics of bridge. 5⅜″ x 8″ x 5⁹⁄₁₆″. 6 lbs.

RU-1 "RUN UP" SOURCE

Combination millivolt and milliampere "run up" source for instrument calibration. Checks newest process controllers and amplifiers. Current source furnished by two self-contained 90V batteries made to give stable, uniform outputs with cold cathode type voltage regulator tube. Self-contained. 5⅜″ x 8″ x 5⁹⁄₁₆″. 10 lbs.

TECHNIQUE ASSOCIATES

TECHNIQUE

A Division of Duncan Electric Co., Inc.

P. O. BOX 91 • INDIANAPOLIS 6, INDIANA

CIRCLE 86 ON READER-SERVICE CARD

A. D. JONES OPTICAL WORKS

2400 MASSACHUSETTS AVENUE

CAMBRIDGE 40 MASSACHUSETTS

TRowbridge 6-3368—3369

A LIST OF MATERIALS WE FABRICATE USED IN OPTICS AND ELECTRONICS

SAWING GRINDING POLISHING DRILLING

ALUM
ALUMINA
ALUMINUM
ANTHRACENE
ARSENIC TRISULPHIDE
BARIUM TITANATE
BISMUTH
BRASS
CARBORUNDUM
CERAMIC
COBALT FERRITE
COPPER
*CORNING 707
*CORNING 7052
COPROUS BROMIDE
FERRITE
FERROX
**FLUORIDE, CALCIUM
**FLUORIDE, LITHIUM
GALLIUM ANTIMONIDE
GALLIUM ARSENIDE
GARNET
GERMANIUM
GOLD
INDIUM ANTIMONITE
INDIUM PHOSPHIDE
INDOX
IRON SINGLE CRYSTAL
LITHIUM
MAGNETIC PLUMBITE
MELAMINE FIBER GLASS
MICA, SYNTHETIC
NICKEL OXIDE
PLATINUM
POTASSIUM BROMIDE
*PYREX
*QUARTZ, CRYSTAL
*QUARTZ, FUSED
**SAPPHIRE
**SODIUM CHLORIDE
**STEEL
STRONTIUM TITANATE
TEFLON
TITANIUM DIOXIDE
*VYCOR
*X-RAY LEAD GLASS
ALL TYPES KNOWN GLASS

* Carried in stock
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CIRCLE 87 ON READER-SERVICE CARD

NEW

TWIN CONTACT MINIATURES

DC-AC CHOPPERS

Eleven types, both single and double pole.

Long life.

Low noise level.

Extreme reliability.

Write for Catalog 515.

STEVENS INCORPORATED ARNOLD

7 ELKINS STREET
SOUTH BOSTON 27, MASS.

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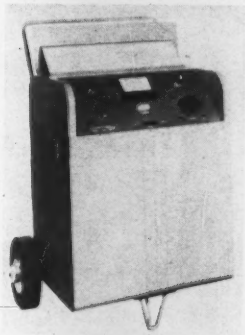
CIRCLE 88 ON READER-SERVICE CARD

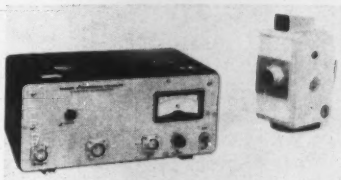
INSULATION TESTERS



New Mobile Hypot high-voltage a-c Testers of insulation dielectric strength have outputs to 20 kv at 10 kva and to 30 kv at 5 kva. Larger ratings in console models. Output is continuously variable from zero to max; 4½" rectifier-type kilovoltmeter connected directly across high voltage output assures accurate measurements.—*Associated Research, Inc., 3777 W. Belmont Ave., Chicago 18, Ill.*

CIRCLE 241 ON READER-SERVICE CARD

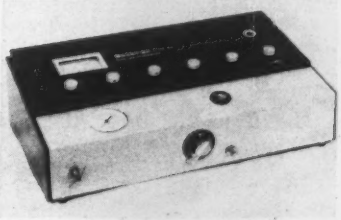
RADIATION THERMOMETER



New Model 14-310 Portable Radiation Thermometer measures radiation from remote water surfaces, clouds, backgrounds, etc. from 15° to 85°F, accurate to ±1.5°F. Detects temp differentials as small as 0.5°F. Spec Sheet 14-310.—*Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn.*

CIRCLE 242 ON READER-SERVICE CARD

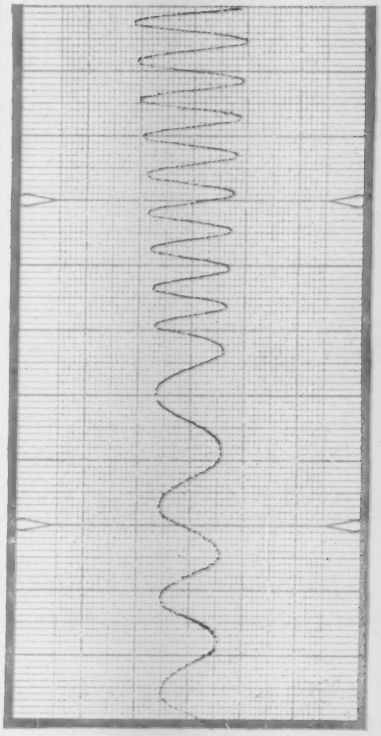
GAS CHROMATOGRAPH



New GC-2A Gas Chromatograph uses thermal-conductivity filament detection system with fast response full-flow-cell geometry. Shows Dimbat-Porter-Stross sensitivity of 10,000 to 12,000 under favorable conditions; 5,000 at noise level less than 0.02 mv, normal (10 to 20 times greater than other filament detectors). Bulletin 787.—*Beckman Scientific and Process Instruments Div., Beckman Instruments, Inc., 2500 Fullerton Rd., Fullerton, Calif.*

CIRCLE 243 ON READER-SERVICE CARD

AO TRACEMASTER PRODUCES SUPERIOR DEFINITION AND UNIFORMITY OF TRACE



The unique carbon transfer writing method of AO's TRACEMASTER 8-channel recorder provides a trace that is a minimum of 2-3 times finer than that of any other direct writing recorder. The trace shown above, taken from a TRACEMASTER record, is an excellent example of the fine trace ...each line is separate and distinct, and reveals significant detail with great clarity.

This allows twice as many lines per millimeter, *or twice the definition,* possible with any other recorder. Notice, also, how the line width and line contrast remain uniform through a chart speed change of 5:1, and through the coincident amplitude change. You continue to see complete signal information.

Superior definition—due to uniform, fine line and excellent contrast—is just one of the many reasons why the AO TRACEMASTER is the world's finest direct writing recorder. Write for complete information, now!

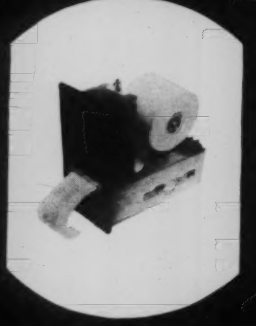
American Optical Company

Instrument Division • Buffalo 15, New York

CIRCLE 89 ON READER-SERVICE CARD

NEW

PRINTING COUNTERS



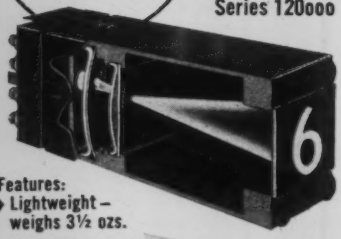
SIX DIGIT AC OR DC COUNTERS. ELECTRICAL RESET TO ZERO. ADD AND/OR SUBTRACT MODELS. SPEEDS UP TO 3000 COUNTS PER MINUTE. OPTIONAL PROGRAMED PRINT/RESET CYCLES.

A. J. BARANOFF & ASSOC.
1214 PARK LANE, SANTA ANA, CALIF.

CIRCLE 90 ON READER-SERVICE CARD

MINIATURIZED! LIGHTWEIGHT!

IN-LINE DIGITAL READOUT
Series 120000



Features:
- Lightweight – weighs 3½ ozs.
- Quick disconnect at rear for easy lamp replacement.

PRICE COMPLETE $35.00

Quantity Prices On Request

WRITE TODAY FOR COMPLETE SPECIFICATIONS

Representatives in principal cities

Over 1000 firms throughout the world in just a few years prove unprecedented acceptance of IEE digital readouts.

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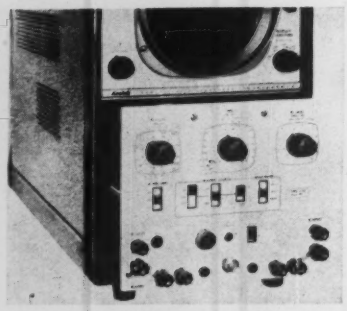
NORTH HOLLYWOOD, CALIF.

IEE

CIRCLE 91 ON READER-SERVICE CARD

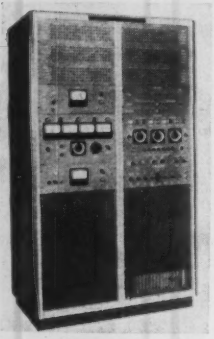
DUAL-CHANNEL PLUG-IN



New Type 200 Dual-Channel Plug-In provides dc to 500 kc bandwidth and 1 mv/cm sensitivity for use with Analab Oscilloscope Main Frames. Contains trigger sweep circuits and two amplifier channels. Sweep range calibrated from 0.5 sec/cm to 1 μsec/cm in 18 calibrated ranges on 10-cm time base.—*Analab Instrument Corp., 30 Canfield Rd., Cedar Grove, N. J.*

CIRCLE 244 ON READER-SERVICE CARD

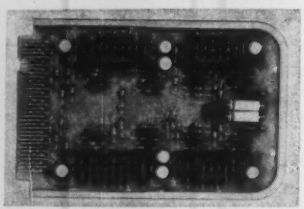
CIRCUIT ANALYZER



New Model 8524 high voltage Automatic Circuit and Cable Analyzer checks up to 120 circuits for continuity, insulation resistance and high voltage breakdown. Tests every light, timer, meter, relay and circuit in complete assembly; also checks itself for malfunction. Bulletin 8-65.1.—*Associated Research, Inc., 3777 W. Belmont Ave., Chicago 18, Ill.*

CIRCLE 245 ON READER-SERVICE CARD

1-MC LOGIC PACKAGES



New Model BC-30 digital module utilizes static circuitry and NAND (not-and) logic; contains 4 1-MC counter stages which may be wired for binary or binary-coded-decimal operation.—*Computer Control Co., Inc., 983 Concord St., Framingham, Mass.*

CIRCLE 246 ON READER-SERVICE CARD

Shore

HARDNESS TESTING

The Shore Scleroscope for testing the hardness of metals and other materials. Accurate, rapid, completely portable, non-marring. Over 40,000 in use. Pioneer American standard since 1907.
The Shore Durometer for testing the hardness of rubber and rubber-like materials. May be used free hand or mounted on Operating Stand. Conform to ASTM D676, D1484, & D1706.

Shore

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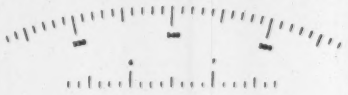

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CIRCULAR
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For printed circuits, i.e., commutators, switches, and general circuitry

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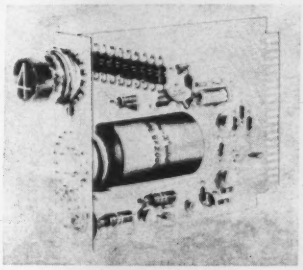
CIRCLE 95 ON READER-SERVICE CARD

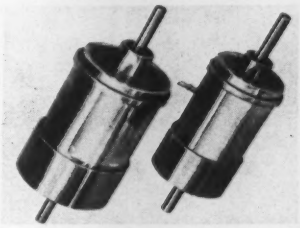
DECADE COUNTER



New DC-114 Transistorized Decade Counter uses Shielded BEAM-X switch, which permits counting tube and visual readout to be mounted on single plug-in module, eliminates 90 components normally required. For frequencies to 110 kc, provides 10 constant current outputs for printing, gating, or presetting.—*Burroughs Corp., Electronic Tube Div., Box* 1226, *Plainfield, N. J.*

CIRCLE 247 ON READER-SERVICE CARD

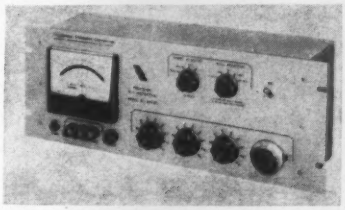
BRAKE-CLUTCHES



New electrically operated Brake-Clutches have BuOrd mountings, are used in configurations requiring fast stopping or starting, or engagement or disengagement from continuously running driving sources. Size 11 Brake-Clutch has 16 in-oz brake or clutch torque, 23-msec total response time from brake-disengage to clutch-engage. Size 8 brake-clutch has 8 in-oz min torque.—*Bowmar Instrument Corp.,* 8000 *Bluffton Rd., Fort Wayne, Ind.*

CIRCLE 248 ON READER-SERVICE CARD

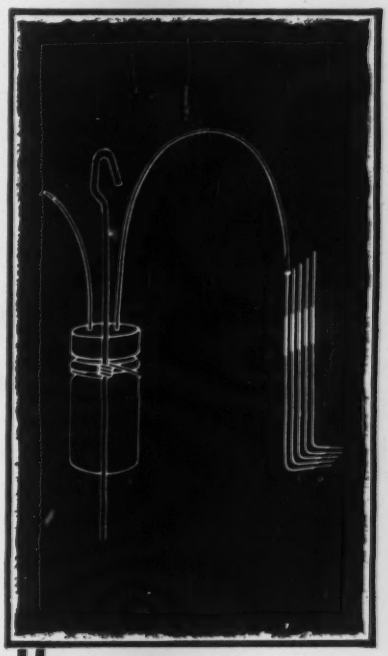
PRECISION VOLTMETER



New Model DC 200AR transistorized DC Voltmeter features self-calibration, warm-up in less than 30 min, accuracy to ±0.01% +5 μv. Range 0-1000 v dc, potentiometer accuracy of ±0.002%, temp stability of 2 ppm°C from 10° to 40°C, regulation of ±0.001% for 10% line change.—*Calibration Standards Corp.,* 1025 *Westminster Ave., Alhambra, Calif.*

CIRCLE 249 ON READER-SERVICE CARD

CANNON PENS



UP TO A YEAR WITHOUT REFILLING

Cannon Meter Pens are easily installed as original or replacement equipment in all standard recording instruments. Produce accurate charts of maximum legibility. No blurring or smearing.

- Ends unrecorded intervals. Unaffected by pulsating flows, chart speeds, or rapid pen movement.
- Sealed ink supply prevents clogging from atmospheric contamination.
- Two-way capillary action ink flow eliminates smearing, blurring.
- Available in five sizes and angles. Special pens designed to customer specifications on request.

Write today for information.

AMERICAN METER CO. EST. 1836

AMERICAN METER COMPANY

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CIRCLE 96 ON READER-SERVICE CARD

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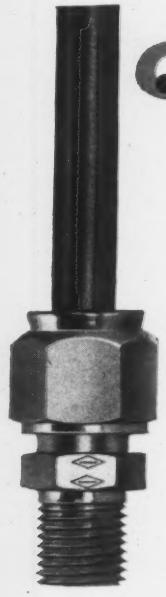
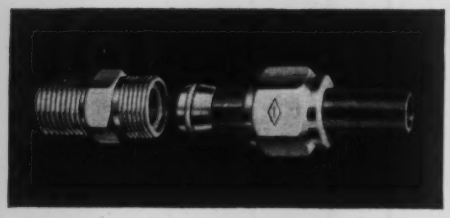


one versatile fitting



to meet more pressure, temperature, shock, vibration conditions than does any other tube fitting

. . . in more styles, sizes, combinations and materials than any other fitting. For more information, see next page . . . and write for Catalog 3108.

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IMPERIAL EASTMAN

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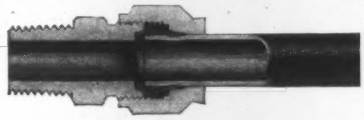
CIRCLE 97 ON READER-SERVICE CARD

one

tube fitting— versatile Hi-Seal®

With Hi-Seal you can overcome moderate to toughest service conditions—in one entire system or in several. With simple variations in the basic fitting, you meet al-



most every need—just specify a change in type of metal and vary the sleeve and nut. Thus, you match Hi-Seal to pressure, temperature, vibration, shock and installation variables.

50 TYPES—1300 SIZES

Hi-Seal Fittings are available in straight connectors, straight reducers, unions, adapters, elbows, tees, crosses, caps, couplings, swivel nuts, valves, port seal and Braze-Seal. Altogether there are almost 50 types—collectively more than 1300 sizes, generally from 1/16" tube O.D. to 1½". Metals available include steel, stainless steel, brass, aluminum, titanium, Monel and others. Combinations are almost endless!

Now Imperial-Eastman meets all your requirements for hydraulic-pneumatic-flow system components: tube fittings, valves, couplings, flexible and rigid hydraulic and pneumatic lines, thermoplastic tubing, tubing tools.

See Imperial-Eastman first!

FITTINGS

IMPERIAL-EASTMAN

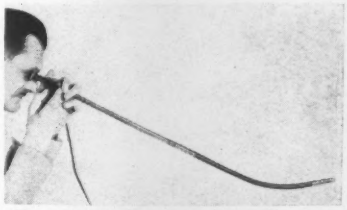
CIRCLE 97 ON READER-SERVICE CARD

DATA TRANSMITTER

New Dial-o-Verter System, in connection with Bell System's Data-Phone 200 subset, transmits punched card, paper tape, or magnetic tape data over regular toll telephone lines. Minimum rate for any terminal is 100 characters/sec (1000 words/min). All terminals use common language; any type of terminal communicates with same or any other type. Includes error-checking facilities. Transmitter or receiver operable unattended.—*Digitronics Corp., Albertson Ave., Albertson, L. I., N. Y.*

CIRCLE 250 ON READER-SERVICE CARD

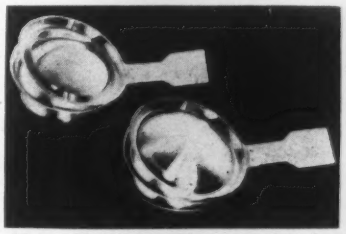
INSPECTROSCOPE



New 9-mm-dia scanning-mirror and adjustable focusing Model ECM-S Inspectroscope has mirror and movable tip remote-controlled by fine gear mechanism. Scanning movement of mirror increases field of vision 2½ times. Magnification ranges from 10 power at window to 1 power at focal length of 2". Models from 15" to 48" long. Leaflet 230.—*Eder Instrument Co., 2293 N. Clybourn Ave., Chicago 14, Ill.*

CIRCLE 251 ON READER-SERVICE CARD

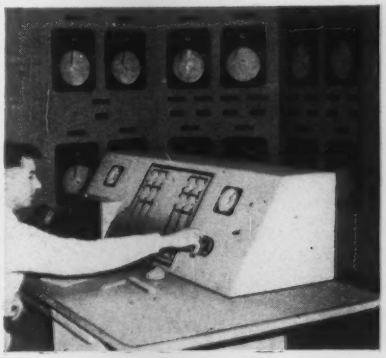
RUPTURE DISCS



New Rupture Discs made from various thicknesses of ductile metals, range from ⅛" through 30", for pressures from 5 to 50,000 lb. Types H-O and H-O-V withstand operating pressures closer to rupture pressure than has been considered acceptable for conventional prebulged rupture discs. CPV disc of low rupture pressure is resistant to handling damage.—*Fike Metal Products, Blue Springs, Mo.*

CIRCLE 252 ON READER-SERVICE CARD

AUTOMATION ECONOMY

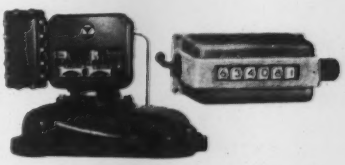


FOR YOUR SYSTEM

American® telemetering and telecounting equipment helps one man do the work of many ...in gathering fields, transmission and distribution systems.

One man at a central dispatching station instantly receives accurate flow and pressure readings from remote points and adjusts for demand with remote-set controllers.

For further information consult your American representative.



American Telecounters accurately transmit Base Volume Index indications of gas quantities computed to base temperature and base pressure conditions, to central locations.

AMERICAN® METER COMPANY

INCORPORATED (ESTABLISHED 1874)

General Offices: Philadelphia 16, Pa.
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CIRCLE 99 ON READER-SERVICE CARD

. . . her conscientious workmanship watches over

RECORDING CHART RELIABILITY

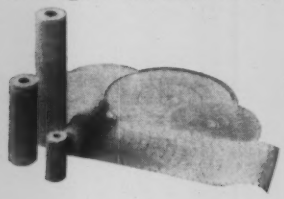
"Dish" occurs at the core end of a roll chart wound with incorrect tension. It means loose winding — and can lead to trouble.

Lois Deinhart, one of GC's experienced rewind operators, helps prevent this trouble from ever occurring. Here she is operating one of a battery of high speed precision rewind machines that roll strip charts to the exact length and tension required. Inspection by Lois and other skilled operators allows only perfect rolls to pass for shipment.

Because of special equipment and specially talented people, GC has become the world's largest manufacturer of recording charts—producing rolls, for instance, for virtually every make of strip chart recording instrument on the market. Over 70 different types of cores are available, each suited to the requirements of a specific instrument. End of roll indicators can be provided for visual, mechanical or electronic alarms.

GC's stock catalog lists over 15,000 different types of circular, strip and rectangular charts. We also design and produce special purpose charts to fit your most exacting needs.

More than 5,000 chart users have come to rely on GC Recording Charts for accurate, dependable performance—chart after chart—year after year. In fact, GC Charts must be good to sell so well for so long. Try them yourself! Let us send you our complete Stock List, and sample charts for one of your instruments.



RECORDING CHARTS

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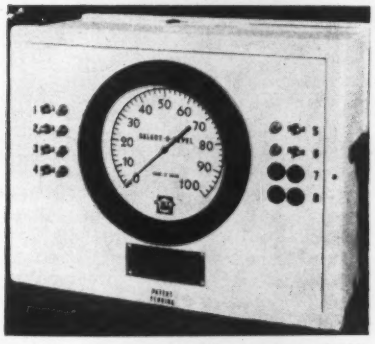
CIRCLE 100 ON READER-SERVICE CARD

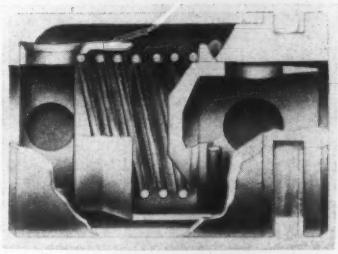
LEVEL INDICATOR



New Select-O-Level, remote indicating device for reading level of corrosive and non-corrosive liquids stored in non-pressure tanks, can be 500′ from tanks and read levels to 33′. Through use of selector switches, 12″ dial gives readings for up to 8 tanks on one model (shown), up to 16 tanks on another. Pilot lights indicate tank being read.—*Barnard & Leas Mfg. Co., Inc.*, 1200-34 12 *St., SW, Cedar Rapids, Iowa.*

CIRCLE 253 ON READER-SERVICE CARD

CARTRIDGE CHECK VALVE



New C-200 Cartridge Check Valve fits single bored hole, avoiding bulky complicated piping and saving over 75% installation costs. Available in steel or aluminum from ⅛″ to ¾″, operates at pressures to 5000 psi. Circle Seal cage device restrains O-ring, prevents washout. Dead tight sealing and chatter-free operation.—*Circle Seal Products Co., Inc.*, 2181 *E. Foothill Blvd., Pasadena, Calif.*

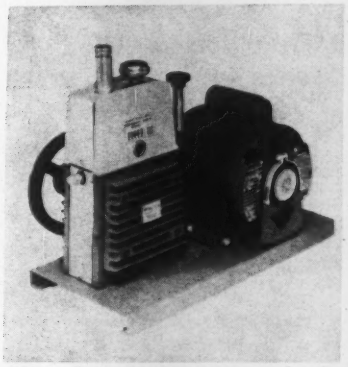
CIRCLE 254 ON READER-SERVICE CARD

MILLIMICROAMMETER

New Model 1811AR Millimicroammeter is rack mounted for measuring low level currents from less than 1 μa to 3 ma. Features high gain chopper stabilized amplifier with feed back that eliminates zero adjust; full scale voltage drop of 10 mv on all ranges.—*Dynatran Electronics Corp.*, 178 *Herricks Rd., Mineola, N. Y.*

CIRCLE 255 ON READER-SERVICE CARD

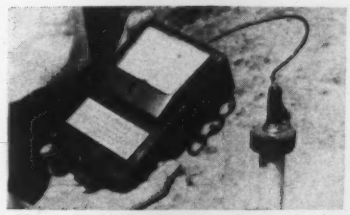
VACUUM PUMP



New S14 single-stage mechanical Vacuum Pump uses internal vane principle with gas ballast, has oil-sealed pump rated at 140 liters/min at atmospheric pressure. Will pump down to 10 microns of mercury. Booklet 322.—*Central Scientific Co.*, 1700 *Irving Park Rd., Chicago, Ill.*

CIRCLE 256 ON READER-SERVICE CARD

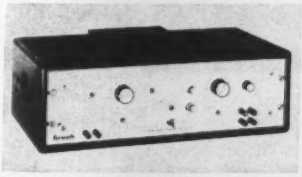
SOIL MOISTURE



New Raincheck transistor instrument for measuring soil moisture consists of probe and reader. Probe (up to 5′ long) is inserted in 1″-dia augered hole. Reader box inserted into probe obtains reading in either % moisture or matric soil suction (ability of soil to hold more water).—*Communications Control Corp.*, 14707 *Keswick Ave., Van Nuys, Calif.*

CIRCLE 257 ON READER-SERVICE CARD

RECORDER PREAMP



New Industrial Analyzer Model RD 4627 00 adapts medium gain recording systems to wider range of recording applications; in conjunction with systems such as Brush Recorder Mark II and RD 1684, records from strain gage and other resistive transducers together with thermocouple, piezoelectric and similar low-level output sensors. Applications include analysis of welding forces and currents, structural strains vs temp, thermal shock studies, etc.—*Brush Instruments, Div. Clevite Corp., 37th and Perkins, Cleveland 14, Ohio.*

CIRCLE 258 ON READER-SERVICE CARD

EVERY USER OF OSCILLOGRAPHS should have this FREE PORTFOLIO

This portfolio, yours for the asking, tells eight ways you'll benefit by standardizing on GC direct-writing charts. It holds a sheaf of samples to give you the "feel" of the ultra-smooth, specially milled paper on which GC Charts are printed. On the back is a handy guide for ordering the GC direct-writing charts that will meet your needs.

For unique convenience, you can place a single order for a whole year's supply of GC direct-writing charts specifying periodic shipments to meet your needs. Right now, get the complete story. Write:

RECORDING CHARTS

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Please send me your new portfolio of information and samples of GC direct-writing charts. No charge or obligation, of course.

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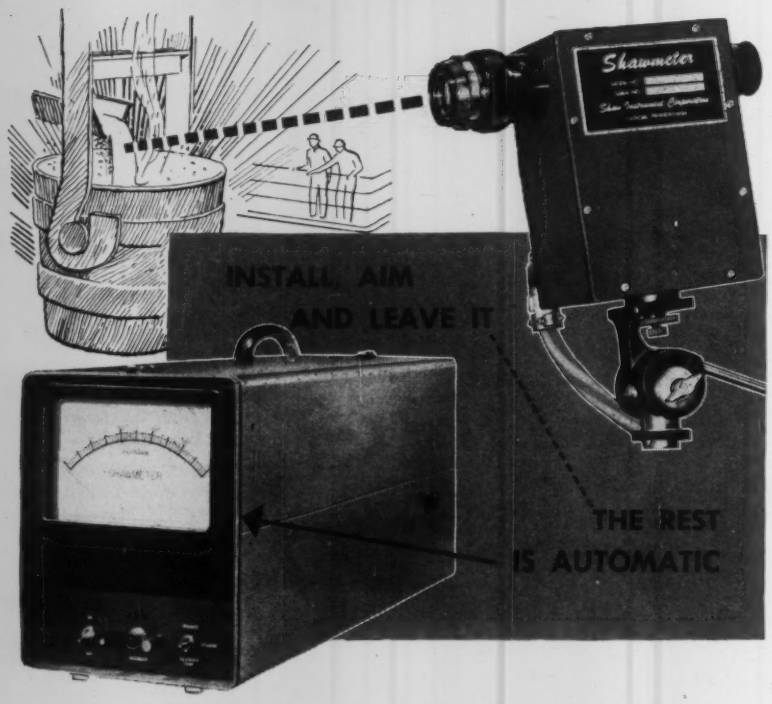
CIRCLE 101 ON READER-SERVICE CARD

Measure High Temperatures

EASILY, ACCURATELY

with the

SHAWMETER®



The SHAWMETER is an automatic, direct-reading, two-color pyrometer for indicating, recording or controlling temperatures up to 6500°F.

Measures the temperature of flowing metal, or of moving or stationary objects. No emissivity correction needed. Temperatures may be measured at a considerable distance from the object.

Accurate, sensitive, rugged. Write for complete details.

SHAW INSTRUMENT CORPORATION

CERAMIC-METAL SEALS • NUCLEAR and ELECTRONIC INSTRUMENTATION

P. O. Box L-46 Latrobe, Pennsylvania

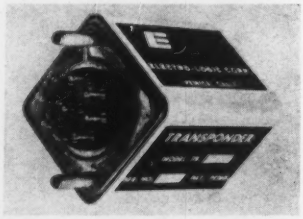
CIRCLE 102 ON READER-SERVICE CARD

PRESSURE TRANSDUCER

New solid-state piezoresistive Pressure Transducer has output voltage approx 20 times greater than wire strain gage, temp range —65° to 350°F, natural frequency greater than 4 kc, dynamic frequency response from 0-1000 cps. Available in ranges from 0 to 25, 100, and 500 psig.—*Gulton Instrumentation Div., Gulton Industries, Inc., 212 Durham Ave., Metuchen, N. J.*

CIRCLE 259 ON READER-SERVICE CARD

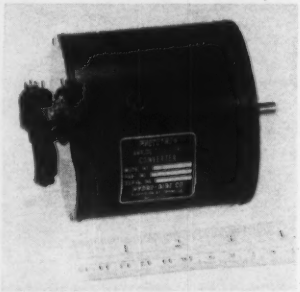
AN/DIG CONVERTER



New ElCon and Micro-Con Transponders permit direct conversion of transducer signals into digital outputs. Former responds to interrogating pulse with new pulse proportional in duration to transducer input voltage. Micro-Con respond to chain pulse interrogation, producing output pulse train proportional in number of pulses to transducer input voltage. Accuracies available to 0.1% absolute.—*Electro-Logic Corp., 515 Boccaccio Ave., Venice, Calif.*

CIRCLE 260 ON READER-SERVICE CARD

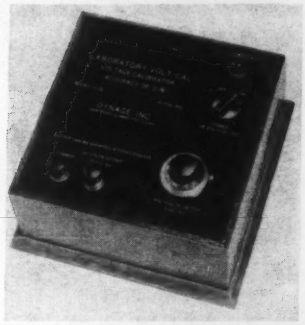
SHAFT ANGLE CONVERTER



New Phototron, transducer for incrementally converting shaft angle to digital measurement information, available in 7 models, operates on principle of interruption of light beam by slotted disc. Max speed varies from 15,000 rpm at 128 counts/rev to 1,250 rpm at 2,048 counts; sampling rate to 45,000 counts/sec.—*Electronics Div., Hydro-Aire Co., 3000 Winona Ave., Burbank, Calif.*

CIRCLE 261 ON READER-SERVICE CARD

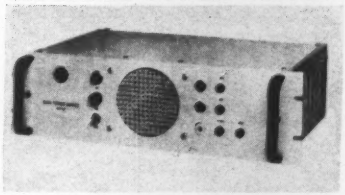
VOLTAGE CALIBRATION



New laboratory voltage Volt-Cal calibrates self-balancing potentiometers, oscillographs and instruments having high input impedance. Operates from 115v ac (±20%). Standard ranges are 0 to ±1000mv, 0 to ±100 mv, 0 to ±10mv dc. Voltage stability ±0.01% or less for line voltage variations of 94 to 140 v. Temp stability ±0.002%/°C from 0° to 40°C. Linearity ±0.05%; overall accuracy using sum of worst stability conditions, 0.1% full scale. Spec PS 300-1.—*Dynage, Inc., 75 Laurel St., Hartford, Conn.*

CIRCLE 262 ON READER-SERVICE CARD

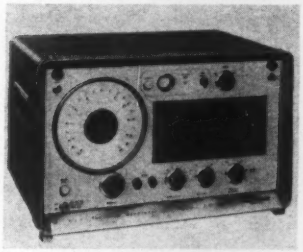
MULTIPLE POWER SUPPLY



New Model B Data Power Unit is rugged, standard product that provides all of voltages required for most medium-size digital systems. Fits 19" relay rack.—*Harvey-Wells Electronics, Inc., 14 Huron Dr., Natick, Mass.*

CIRCLE 263 ON READER-SERVICE CARD

FUNCTION GENERATOR



New SG88 V.L.F. Function Generator provides any waveform at repetition rates down to one cycle every 200 seconds for solution of simulation and computer design problems, for servo-system analysis, vibration testing, etc. Unit eliminates need for specially shaped and wound potentiometers and complex electronic waveshaping circuits.—*General Measurements Co., Inc., 1108 Beacon St., Newton Highlands 61, Mass.*

CIRCLE 264 ON READER-SERVICE CARD

CIRCLE 103 ON READER-SERVICE CARD→

Production leak testing of big components

NOW 4 TIMES FASTER

It takes just one minute instead of four to evacuate this bell jar and to leak check the large part inside. This high speed is provided by CEC's new 24-120 Leak Detector and 24-025A Test Port Station combination, which leak checks sealed components four times faster than any other mass spectrometer leak detection system.

What gives this system such speed? A 2-in. manifold and high capacity vacuum-operated valve in the test port station that permit full use of a 13 cu. ft./min. vacuum pump —*plus* superior vacuum geometry that gives the leak detector fast response.

By combining this remarkable test port station and leak detector, smaller components also can be leak checked . . . at the rate of one part every 8 seconds.

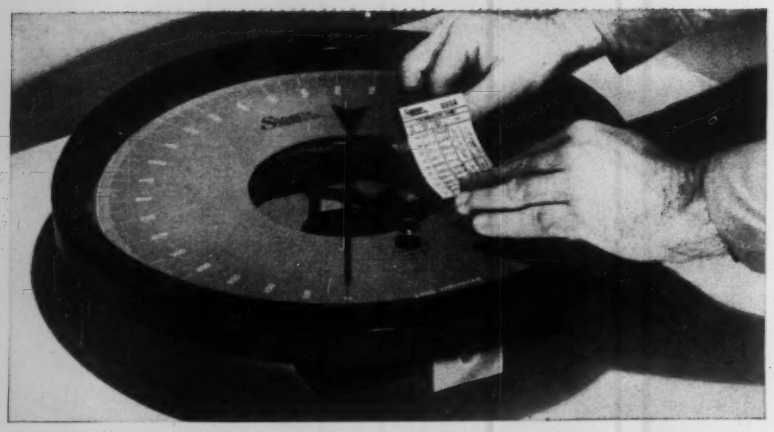
The 24-120 instantly locates leaks as small as 5×10^{-11} atm./cc./sec. of air (4.8×10^{-6} micron cu. ft./hr.). Used independently, it provides proof of seals in all sizes of equipment, containers, and systems.

For more information, write for Bulletin CEC 24120-X7 or call your nearest CEC sales and service office.

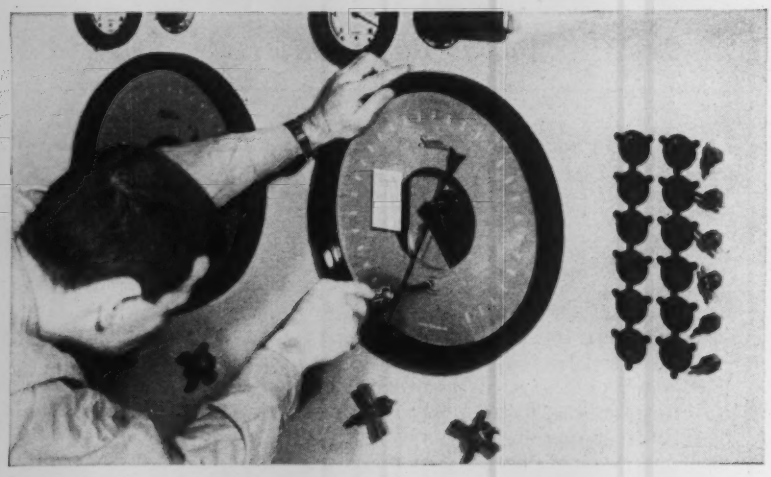
Analytical & Control Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

A SUBSIDIARY OF Bell & Howell · FINER PRODUCTS THROUGH IMAGINATION



Guaranteed accurate
not only when it leaves our factory
but also after field recalibration



You can recalibrate Seegers precision test gauges to their original accuracy of 0.10% FS over their entire pressure range. Simple screwdriver adjustment takes only a few seconds and requires no special tools or testing equipment. Only Seegers gauges have this *true* recalibration capability. Other product superiorities include Ni-Span C and stainless steel components, eye-ease green dial with white increments linear to ±.001", and bourdon bleed and flush valve as standard equipment. *Write for a copy of our comprehensive technical bulletin.* **Seegers Instrument Company**

515 West Main Street, Barrington, Illinois SGS-1-200

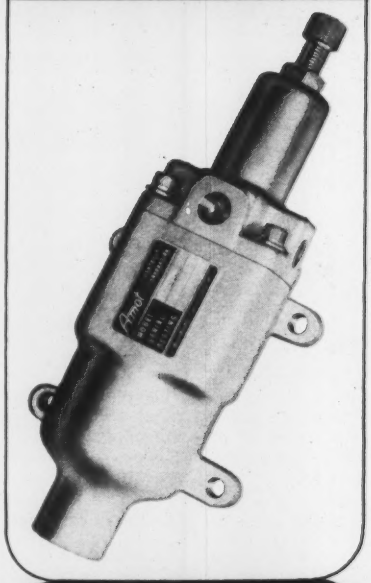
CIRCLE 104 ON READER-SERVICE CARD

NOW!

DETECT AND STOP EXCESSIVE VIBRATION WITH Amot MODEL 2900 VIBRATION VALVE

Amot Model 2900 Vibration Valve detects and trips on excessive vibration of reciprocating or rotating machinery, such as engines, compressors, motors, fans, pumps.

It is offered as an accessory to Amot Series 1476 Safety and Automatic Controls.



FEATURES: Duty: For Pneumatic or Hydraulic Control Systems to 80 psi.

Operation: Three-way, snap acting, non-overlap valve action.

Range: Adjustable to amplitudes between .004" and .050" at 250 cpm and between .003" and .023" at 700 cpm or higher.

Reset: Built-in piston to reset control with 45-80 psi air; also provides means for time delay on start-up.

Write for Bulletin 493

Amot controls CORPORATION

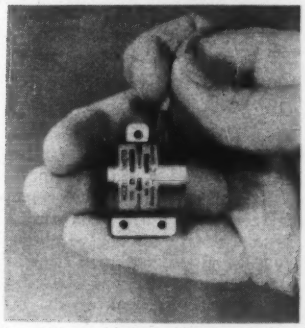
THERMOSTATS CONTROLS SWITCHES VALVES SAFETY CONTROLS

4111G FIRST ST. • RICHMOND, CALIF., U.S.A.

CIRCLE 105 ON READER-SERVICE CARD

NEW INSTRUMENTS

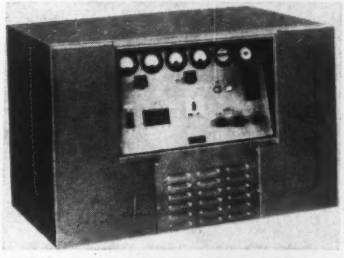
STRAIN-GAGE ACCELEROMETER



New Type 4-203 linear unbonded strain gage bidirectional Accelerometer with 4 active-arm spring-type sensing element is available in ranges from ±5 to ±500 g. Measures accelerations parallel to mounting surfaces, operates from −70° to +300° F. Sensitivity to acceleration perpendicular to sensitive axis less than 0.01 g/g; damping is 0.7±0.1 of critical at 77°F; combined linearity and hysteresis less than ±0.75% of full range output.—*Consolidated Electrodynamics Corp., Subs. Bell & Howell, 360 Sierra Madre Villa, Pasadena, Calif.*

CIRCLE 265 ON READER-SERVICE CARD

LAB POWER CENTERS



New Laboratory Power Centers consist of motor-alternators providing 60 cps, 3φ, 4-wire, and 400 cps, 3φ, 4-wire service, and alkaline battery pack providing 24-28 v dc, equipped with a "floating" charger. Series LPC-210 provides 5 kw at 400 cps, 1.0 to 0.8 P.F; Series LPC-230 provides 15 kw at each frequency.—*Electric Specialty Co., Div. Electronic Specialty Co., 211 South St., Stamford, Conn.*

CIRCLE 266 ON READER-SERVICE CARD

TOP ENTRY BALL VALVES

New 1"-8" industrial 150-psi Flo-Ball valves feature top entry for easy maintenance, Teflon seats and seals. Removing bonnet flange permits access to ball and seats with valve in line; tightening 2 hex nuts on bonnet adjusts seat.—*Hydromatics, Inc., 5 Lawrence St., Bloomfield, N. J.*

CIRCLE 267 ON READER-SERVICE CARD

How to produce better
POTENTIOMETERS
without increasing costs

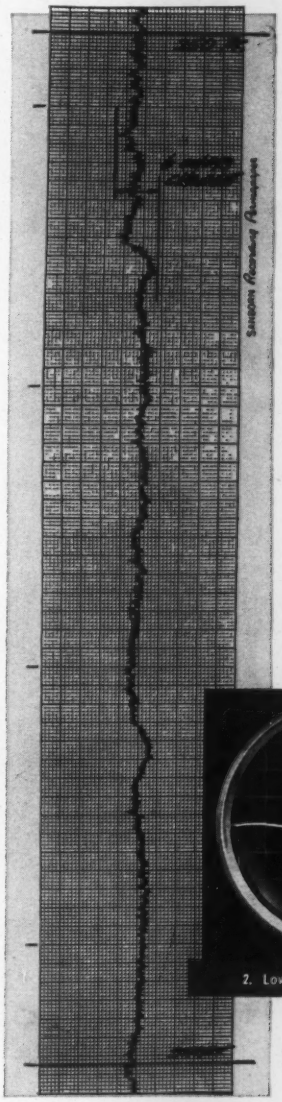
Use Hoskins
Chromel-R
Premium Potentiometer Grade Wire

a new custom-quality nickel-chromium alloy especially developed, processed and controlled to assure you of:

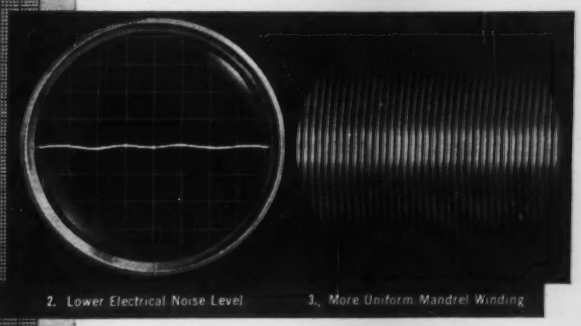
1 Closer independent linearity, with maximum total deviation continuously controlled to within .012% over any 250 feet of wire.

2 Lower electrical noise level, unconditionally guaranteed to be less than 40 ohms of E.N.R. when received at your plant.

3 Greater efficiency in winding mandrels—with more uniform spacing between turns—due to its superior wire roundness.



1. Closer Linearity of Wire Resistance



2. Lower Electrical Noise Level 3. More Uniform Mandrel Winding

If you make POTENTIOMETERS this wire is right for you!

It's premium in quality but not in price. And sample spools plus complete technical data are available now to potentiometer manufacturers for immediate testing and evaluation. Your request on company letterhead will receive our prompt attention.

HOSKINS MANUFACTURING COMPANY
4445 Lawton Avenue • Detroit 8, Michigan
In Canada: Hoskins Alloys of Canada, Ltd., Toronto, Ontario
Producers of Custom-Quality Resistance, Resistor and Thermo-electric Alloy Since 1908

NOW...

ELIMINATE THE HIGH COST OF MAKESHIFT THERMOCOUPLES...

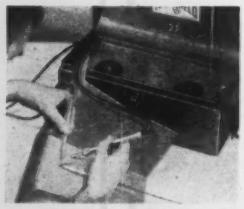
FOR ONLY $12.95

with THE NEW, PRECISION, LOW COST THRIFT/THERM

- **Thrift/Therms release high-salaried technicians for more profitable activity.**
- **Thrift/Therms avoid loss of time and money caused by inaccurate data often produced by makeshift thermocouples.**

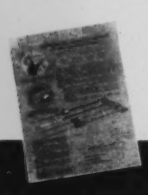
For but $12.95, HARCO Laboratories offers a trial set of THRIFT/THERMS (shown above), the new, miniaturized thermocouple assemblies that have revolutionized the high cost of effective, comprehensive temperature sensing. In 99% of the thermocouple temperature sensing applications, the THRIFT/THERMS' specific performance is guaranteed to equal or surpass that of the most expensive thermocouple. Available in Chromel-Alumel, Iron-Constantan, and Copper-Constantan, these highly accurate, closely calibrated devices can be made to any specified length.

Any Thrift/Therm is ready for immediate use . . . no further adjustments, connections required. All Thrift/Therms have welded junctions. All have a quality type thermocouple connector. These and other exclusive features make it infinitely less expensive to buy Thrift/Therms than to use costly time and materials in attempting to construct your own thermocouples. Order a trial kit today. Checks, purchase orders, money orders—made payable to HARCO—accepted. Further information available.



To assist application of the exposed junction THRIFT/THERM, HARCO also offers the HARCOWELD portable welding kit, designed especially to weld thermocouple junctions directly and rapidly to the surface of larger elements.

Literature available. Inquire.



HARCO Laboratories, Inc.
NEW HAVEN, CONNECTICUT
DEPT. ICS

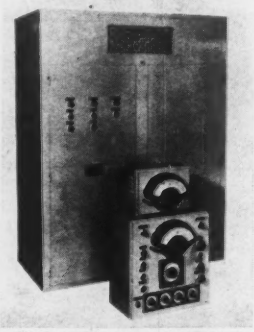
CIRCLE 107 ON READER-SERVICE CARD

PARTICLE COUNTER

New Model C Counter (improved version of Model A) determines particle size distribution on ceramics, pharmaceuticals, air contaminants, etc. from below 1 micron to above 200 microns. Produces full size range data in 10 sec, enabling size distribution studies of unstable materials.—*Coulter Electronics, 2525 N. Sheffield Ave., Chicago 14, Ill.*

CIRCLE 268 ON READER-SERVICE CARD

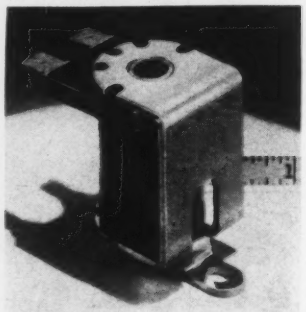
X-RAY GAGE



New X-ray Gage penetrates carbon steel plate up to 2" thick, has sensing equipment mounted in "C" yoke with 30" air gap between pick-up head above plate and X-ray source unit below.—*Daystrom Inc., Weston Instruments Div., 614 Frelinghuysen Ave., Newark 12, N. J.*

CIRCLE 269 ON READER-SERVICE CARD

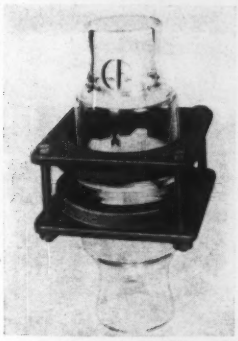
SOLENOID VALVE COILS



New nylon encapsulated coil, used on most Dole valves, provides same electrical performance as coils enclosed in metal cans but gives higher mechanical and electrical strength, is more impervious to moisture.—*Dole Valve Co., 6201 Oakton St., Morton Grove, Ill.*

CIRCLE 270 ON READER-SERVICE CARD

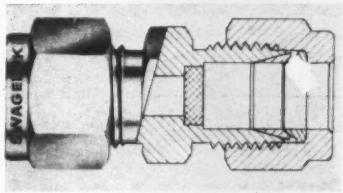
VERTICAL CHECK VALVE



New pyrex and teflon Vertical Check Valve provides visibility and corrosion resistance except to hydrofluoric acid and hot concentrated caustics. Patented lip seal on seat assures positive sealing; body design provides high flow rates at low pressure drop. Max operating pressure 50 psi; 1", 1½", 2" and 3" sizes. Bulletin CV-1.—*Chem Flow Corp.*, 117 *Paterson Ave., Little Falls, N. J.*

CIRCLE 271 ON READER-SERVICE CARD

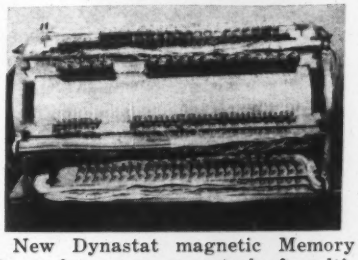
SNUBBER



New Swagelok Snubber Tube Fitting provides dampening effect, prevents damage to costly equipment from sudden flow surges. Filters liquids and gases, especially in low flow lines such as pressure gage lines. Available in standard tube fitting shapes, ⅛"-⅜" OD with type 316 Stainless or bronze sintered removable elements.—*Crawford Fitting Co.*, 884 *E.* 140 *St., Cleveland* 10, *Ohio.*

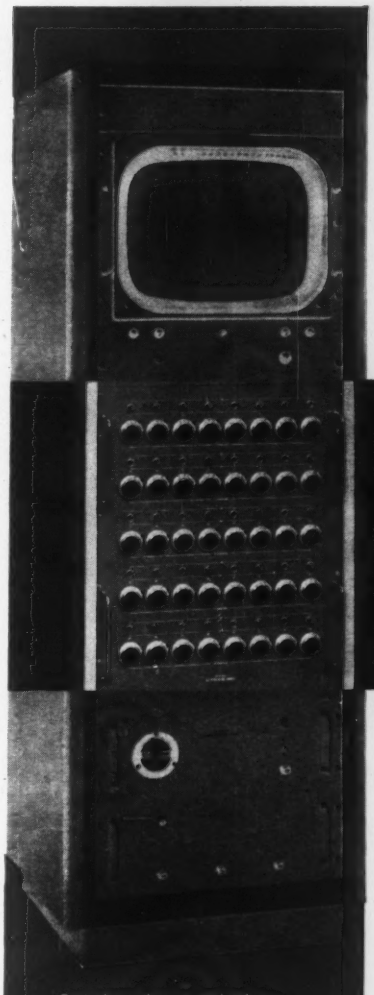
CIRCLE 272 ON READER-SERVICE CARD

MEMORY DRUM



New Dynastat magnetic Memory Drum for program control of multiple-cutting machine operations presents recorded information regardless of speed of rotation on step-by-step basis, remaining stationary while associated machine tool completes cut. Continuously presents information for comparison and control. Dynastat output sufficient to eliminate sensitive amplifiers.—*Consolidated Controls Corp., Bethel, Conn.*

CIRCLE 273 ON READER-SERVICE CARD



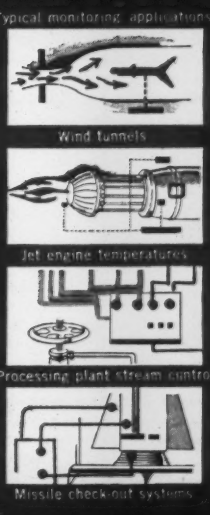
IN ONE
ITT
BAR-GRAPH
OSCILLOSCOPE

40
CHANNEL
READ-OUT

This single, ultra-sensitive display system does the work of 40 separate meters . . . provides quick-look convenience and accuracy for innumerable monitoring applications. Any 40 variables—related or unrelated—that can be converted into electrical signals can be studied, measured, and compared at once on the 17-inch scope of the Model 40BG.

Output of each of the channels is scanned ten times per second by means of a synchronous motor driven switch. Ultra-stable circuits provide maximum accuracy . . . line voltage variations cannot affect performance.

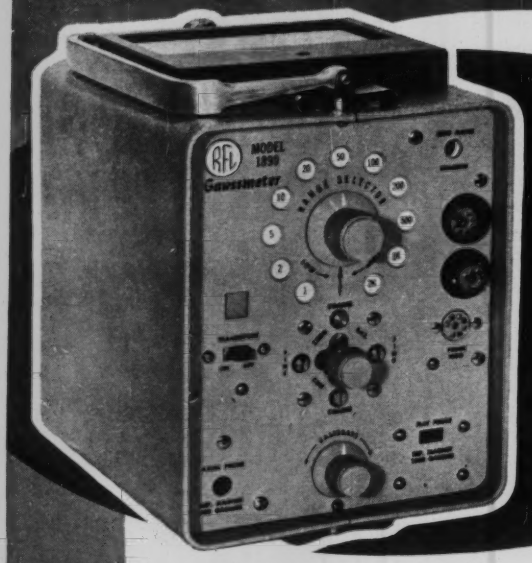
For complete information contact your ITT Instruments representative, or write us for Data File ICS-1022-1.



ITT Industrial Products Division
International Telephone and Telegraph Corporation
15191 Bledsoe Street • San Fernando, Calif. • EMpire 7-6161
static power conversion • instruments • closed circuit television

CIRCLE 108 ON READER-SERVICE CARD

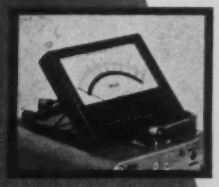
Analyze Magnetic Circuits



Versatile, Transistorized Instrument Measures DC to 400 cps Fields Directly

RFL Model 1890 Gaussmeter

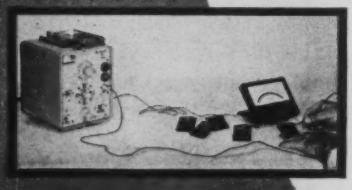
measures flux densities from 0.1 to 20,000 gausses with .01-gauss resolution



Sensitive enough to register half-scale deflection for the earth's magnetic field, the Model 1890 provides a selection of 14 overlapping ranges from 1 gauss full-scale to 20K gausses. Accuracy over all ranges, using standard reference magnet, is better than 3%, with repeatability of meter readings better than 0.5%.

Temperature stable, InAs flat and axial probes are encapsulated in glass reinforced epoxy for durability and safe use around exposed electrical circuits.

The indicating meter is calibrated in gausses, has mirror scale, knife edge pointer and can be adjusted to four positions for most comfortable reading.



Meter has flexible leads, can be removed from cabinet and placed next to magnet structure being measured for most accurate reading. Jacks for external recorder output (1 ma. into 1500 ohm max.) and oscilloscope (2 volts max.) are also provided. Choice of plug-in AC supply or battery pack for portable or field use. Price $430. with flat probe and battery supply.

Performance is rigidly guaranteed. Prices are f.o.b. Boonton, N.J. and subject to change without notice.

SEND FOR TECH. DATA

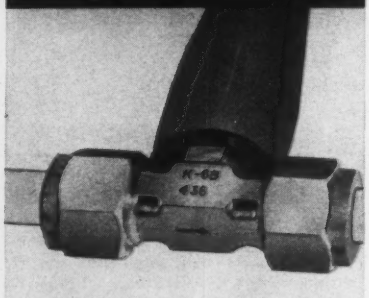
For additional information, including application data, write or phone DE 4-3100. Demonstrations available by local representatives.

Radio Frequency LABORATORIES, INC.
Boonton, New Jersey, U.S.A.

CIRCLE 109 ON READER-SERVICE CARD

HASTINGS (Thermopile) MASS FLOWMETER

measures flow of air, and gases electrically



FEATURES

- high sensitivity—rapid response
- calibration is a function of mass flow
- extreme sensitivity to low flows
- no moving parts—easy operation
- usable from −300°F to +300°F
- undamaged by overload flow or pressure
- rugged and reliable

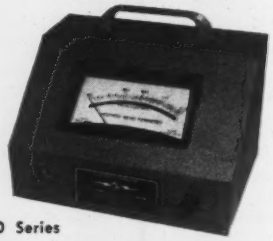
The Hastings Mass Flowmeter consists of an indicator with power supply and a remotely located flow tube which can be installed directly in the line wherever desired. The flow tube incorporates the Hastings patented heated thermopile which is compensated for temperature and rate of change of temperature.

The Thermopile senses mass flow through the tube and produces an electrical output proportional to the mass flow which is indicated on the readout device. All flow tubes are identical and may be interchanged without recalibration of indicator.

The Hastings Mass Flowmeter is available for measurement in

5 RANGES

1) 0-300 Std. cc/min.
2) 100-1000 Std. cc/min.
3) 300-3000 Std. cc/min.
4) 1000-10,000 Std. cc/min.
5) 3000-30,000 Std. cc/min.



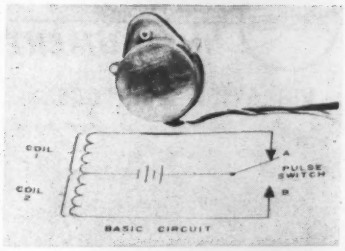
SM-20 Series

For more detailed information send for specification sheet 501. For information on Hastings complete line of Vacuum instruments send for catalog no. 300.

HASTINGS-RAYDIST, Inc.
Hampton, Virginia PArk 3-6531

CIRCLE 110 ON READER-SERVICE CARD

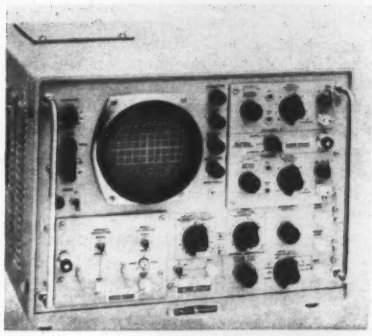
STEPPER MOTOR



New Series 18100 Stepper Motor operates with windings continuously energized in static condition or pulsed at rates to 2400 steps/min, is suited to high speed stepping applications where pulse power is limited. Withstands 100-g shock for 7 ms, and 10-g acceleration; operates from 85° to −54°C. Requires 12.5 msec (min), delivers 80 pulses/sec. Rotor step angle of 30°/cycle. Load is 0.2 oz in at 20°C.—*A. W. Haydon Co., Waterbury, Conn.*

CIRCLE 274 ON READER-SERVICE CARD

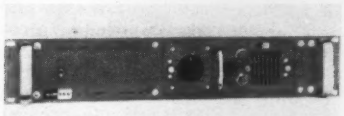
30-MC OSCILLOSCOPE



New 30-Mc Oscilloscope, Model 170A, uses tube-transistor circuits, accepts plug-in verticle amplifiers and series of time axis plug-in units. Provides 24 calibrated sweep times, 0.1 μsec/cm to 5 sec/cm, with ±3% accuracy; 7-range magnifier increases fastest sweep to 0.02 μsec/cm. Nine-range internal calibrator.—*Hewlett-Packard Co.,* 1501 *Page Mill Rd., Palo Alto, Calif.*

CIRCLE 275 ON READER-SERVICE CARD

AMPLIFIER RACK MODULE



New Model 191A Amplifier Rack Module (3½" x 17") holds single 111, 112, or 114 Kin Tel Series amplifier horizontal for mounting in 19" rack. Contains switch, fan, and fused plug. —*Kintel Div., Cohu Electronics, Inc.,* 5725 *Kearny Villa Rd., Box* 623, *San Diego* 12, *Calif.*

CIRCLE 276 ON READER-SERVICE CARD

TIME TEAM

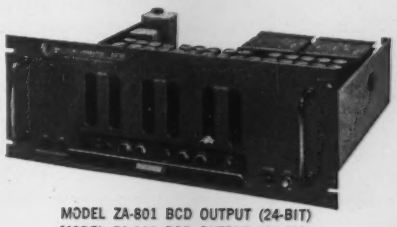
EECO'S ALL-STAR LINEUP OF TIME CODE GENERATORS COVERS ALL THESE BASES

From missile base to basic research, in launching-area heat or Dew-Line cold, Electronic Engineering Company answers your project's time code needs with these outstanding time code generators . . . for binary or BCD readouts, coded for Atlantic Missile Range, Eglin Test Range or the new Inter-Range Instrumentation Group (IRIG) format proposed for world-wide use in satellite tracking.

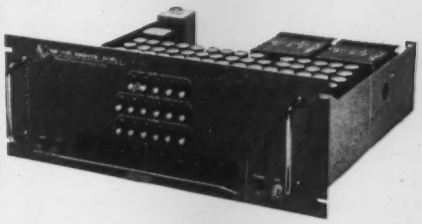
All EECo time code generators can be used with oscillographs, strip chart recorders, magnetic tape or for driving neon flash lamp amplifiers . . . for time-correlation of data recorded by different instruments at one or more sites. All have advance-retard controls for synchronizing internal 1 pps to WWV.

MORE ACCURACY PER DOLLAR with the time code generators shown at right. Both time of day code output (24-hour recycling) and any 2 of 8 pulse rates. Time-correlate data to within ±1 millisecond at a cost of only $7,500 for the ZA-801, $7,000 for the ZA-802. Frequency stability: 3 parts in 10^8 per day.

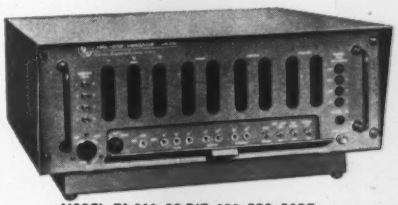
Compact...solid-state plug-in circuits . . . sized for standard rack mounting. Complete unit, including power supply, 7" x 19" x 17".



MODEL ZA-801 BCD OUTPUT (24-BIT)
MODEL ZA-803 BCD OUTPUT (20-BIT)



MODEL ZA-802 BINARY OUTPUT (17-BIT)



MODEL ZA-810 36-BIT 100 PPS CODE
ALSO MODEL ZA-810-M1
23-BIT 2 PPS CODE (IRIG TYPE C)

GENERATES NEW IRIG FORMAT Model ZA-810 (left) and Model ZA-810-M1, solid-state time code generators, use proposed Inter-Range Instrumentation Group formats.

Both generators have same high accuracy as ZA-801 and 802. Packaged plug-in circuits. Complete unit 7" x 19" x 18". Weight only 35 pounds. Price of either model: $10,100.

WRITE FOR TIME CODE GENERATOR FILE 301.
TIMING SYSTEM DESIGN CONSULTATION ON REQUEST.

Electronic Engineering Company *of California*

1601 East Chestnut Avenue • Santa Ana, California • KImberly 7-5501 • TWX: Santa Ana Cal 5263
MISSILE & AIRCRAFT RANGE INSTRUMENTATION • DIGITAL DATA PROCESSING SYSTEMS • TIMING SYSTEMS • COMPUTER LANGUAGE TRANSLATORS • SPECIAL ELECTRONIC EQUIPMENT
EE 0-12 R

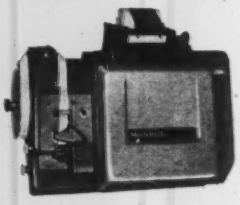
CIRCLE 111 ON READER-SERVICE CARD

MONROE

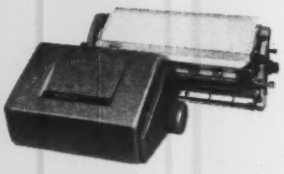
DATA RECORDING WITH MONROE DATA/LOG PRINTERS

MONROE DATA/LOG PRINTER MC-215
Serial entry • Programmable or narrow fixed carriages • One or two accumulators, or print only • 18 digits per second • 142 print cycles per minute • Black and red print • 11 digits per print cycle • 12 digit totals • Motor driven carriage, 82 digits per line • Vertical space on command • Symbol type bars • Pin feed platens • Automatic Line Finder carriage

MONROE DATA/LOG PRINTER MC-205
Parallel input • 5, 6, 7 or 8 channel tape output, any code • 13 or 4¾ inch fixed carriage • One or two accumulators or print punch only • Print and punch 64 cycles per minute • 10 digit maximum plus functional codes punched automatically • IBM card punch output optional • Cabled manual electrical keyboard



MONROE DATA/LOG PRINTER MC-203
Parallel input • Programmable carriage • 3 to 14 digits per print cycle • Up to 4 accumulators with 14 digits each, or print only • Vertical space on command • Carriage return on command • Red print, black print • 2½ print cycles per second • Cabled manual electrical keyboard • Pin feed platens • Symbol type bars



MONROE DATA/LOG PRINTER MC-202
Parallel input • 13 or 4¾ inch fixed carriage • Front feed carriage or around platen carriage • One or two accumulators or print only • Symbol type bars • Cabled manual electrical keyboard • 10 digit maximum • One or two accumulators • 11 digit total • Pin feed platens

DATA/LOG PRINTER WARRANTY. Each Monroe DATA/LOG printer carries a first year's warranty and maintenance guaranty. Following the first year, each unit can be placed on yearly maintenance contract by any of the more than 350 established Monroe service offices in the United States, or by Monroe offices abroad.

Technical specifications and wiring diagrams are available on request.

MONROE DATA/LOG PRINTERS

Call your local Monroe Office or write to:
MONROE Calculating Machine Company, Inc.
Electronics Components Division
60 Main Street,
San Francisco, Calif.

CIRCLE 112 ON READER-SERVICE CARD

IGS NEW INSTRUMENTS

VIBRATION MONITORS

New transistorized Vibration Monitors work with magnetic vibration pick-ups. AC operated Model V/p-2 for general application has 3 vibration ranges: 0 to 0.1, 0 to 1.0, and 0 to 10 mils. On 0 to 100 μin (most sensitive range), measures vibration amplitudes below 10 μin, detects changes of 1 μin. Model V/p-T for pipe line service operates on 48- or 60-v dc with a-c line to actuate calibration circuit; optional feature provides protection with automatic change in scale factor during start-up to avoid false shut-downs.—*Indikon Co., 76 Coolidge Hill Rd., Watertown 72, Mass.*

CIRCLE 277 ON READER-SERVICE CARD

FORCE TRANSDUCER

New Force Transducer senses and measures varying amplitude forces (tension, pressure, weight, thrust, etc.) by using cross-spring (flexure) pivots combined with flat cantilever main spring. Flexure pivots prevent movement of load platform in crosswise or lengthwise planes but allow flexure or bending in third plane. Model TT-100 is for loads from 8 oz-150 lb; Model TT-500, for 50-1500 lb. —*Hydro-Pneu-Tronics, Inc., Force Transducer Sales Div., 3666 E. 116 St., Cleveland 5, Ohio.*

CIRCLE 278 ON READER-SERVICE CARD

Here's 0.1° Sensitivity at a Competitive Price!

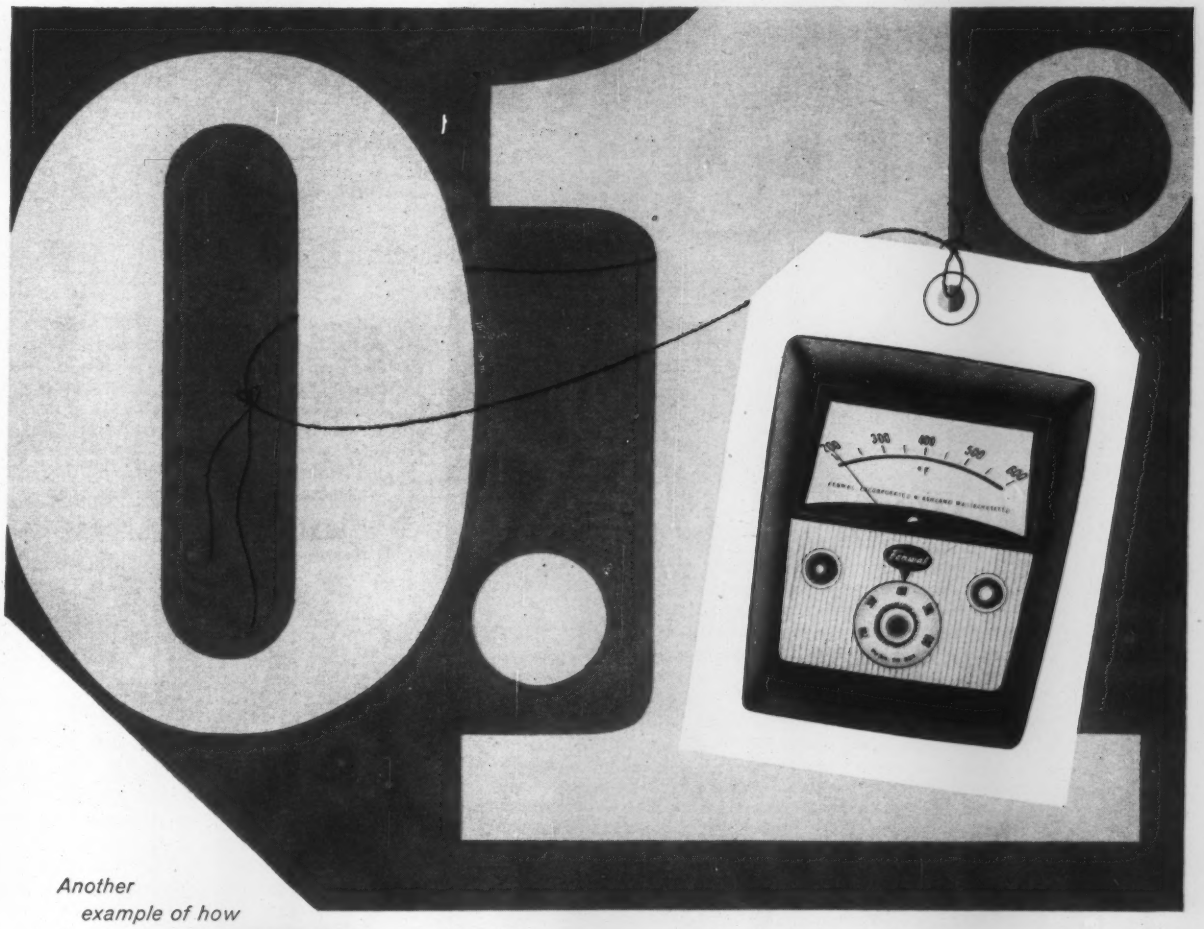
... Fenwal's New "561" Temperature Controller

The new "561" indicating controller responds to temperature changes of 0.1° or less! And is yours at a competitive price! These two features alone make it an instrument you should investigate... but there's more!

You can choose from five standard temperature ranges . . . within the span of −50 to 600°F. Furthermore, scales start and end within *your* ranges, permitting larger graduations, better legibility, easier readout. And control and indication are separate but simultaneous. *Should your indication fail the "561" will continue to control with complete accuracy.*

This precise instrument gives unvarying performance. Its indication and control will not vary with fluctuations of input voltage nor changes in ambient temperature. It offers the option of either ON-OFF or proportional control . . . has 10 AMP/120 VAC relay capacity. Smartly styled to complement modern industrial machines and interiors, *the "561" offers you all these extras at a competitive price.*

A Fenwal engineer will be glad to supply information on the "561", or any other temperature control in Fenwal's broad line. Write Fenwal Incorporated, 362 Pleasant Street, Ashland, Massachusetts.



Another example of how

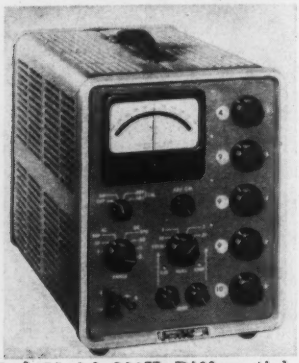
Fenwal CONTROLS TEMPERATURE . . . PRECISELY

CIRCLE 113 ON READER-SERVICE CARD

ANTI-PARALLAX FACE
Anti-parallax BIMET® face eliminates reading errors when dial is viewed from any angle.
STAINLESS STEEL CASE
Stainless Steel Construction throughout, including the most rugged Polished Stainless Steel Case available for the ultimate in corrosion resistance and strength, is exclusively provided on all Moeller BIMETS.
Moeller Features
HERMETICALLY SEALED
Hermetically sealed with dry air to prevent entry of moisture and condensation throughout the life of the instrument.
RECALIBRATION
Exclusive Moeller external recalibration feature provides adjustment of pointer on scale so that scale is always upright and easily readable. Thermometer remains sealed. Only Moeller BIMETS offer the convenience and error-free readability of vertically oriented dials.
Provide Timeless Accuracy
You'll appreciate the superior accuracy, reliability and rugged construction of the NEW 3" and 5" BIMET® Thermometers. Silicone damping stabilizes the pointer against vibration assuring precise reading and reduced wear.
Moeller BIMETS offer superior reliability of measurement, easy, accurate reading, the most rugged construction, simplicity of installation and guaranteed accuracy of 1% of full scale.
The NEW 3" and 5" BIMETS are available for ranges from −100 F to +1000 F or −70 C to +400 C with glass or plastic fronts. Standard ¼" or ⅜" O.D. stems, up to 100" in length may be ordered in any angular position. Moeller exclusive swivel nuts or fixed connections are furnished.
Get your copy of BIMET® Catalog #225D from your Moeller Representative or write
SINCE 1867
MOELLER INSTRUMENT COMPANY, Inc.
132nd Street and 89th Avenue, Richmond Hill 18, N.Y.
Representatives in principal cities.
BIMET® is a registered trademark of Moeller Instrument Company, Inc.

CIRCLE 114 ON READER-SERVICE CARD

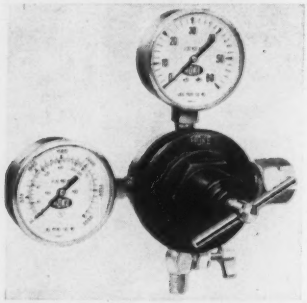
DIFF DC VOLTMETER



New Model 801H Differential DC Voltmeter features infinite input resistance at null over 0-500 v range, 0.05% accurate from 0.1-500 v; recorder output-1-mv full scale, uses taut-band suspension meter.—*John Fluke Mfg. Co., Inc., Box* 7161, *Seattle* 33, *Wash.*

CIRCLE 279 ON READER-SERVICE CARD

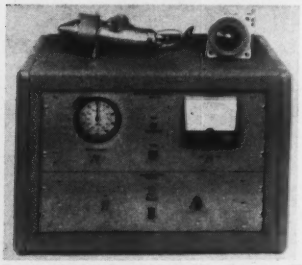
PRESSURE REGULATOR



New 680 Series provide delivery pressures to 140 psi, rated flows to 2000 scfh air, accuracy of 2%. Cylinder pressure gages have safety backs; pre-set relief valve in downstream system of each regulator. Max inlet pressure 2500 psi.—*Hoke Inc., 1 Tenakill Park, Cresskill, N. J.*

CIRCLE 280 ON READER-SERVICE CARD

WALL THICKNESS GAGE



New Model 130 Nuclear Wall Thickness Gage non-destructively measures thin walls having narrow internal channels, does not require AEC license. Uses 0.03" max dia radiation probe placed internally so that soft gamma radiation travels through wall to be measured.—*Franklin Systems, Inc.,* 2734 *Hillsboro Rd., West Palm Beach, Fla.*

CIRCLE 281 ON READER-SERVICE CARD

Both a

PROGRAMMER

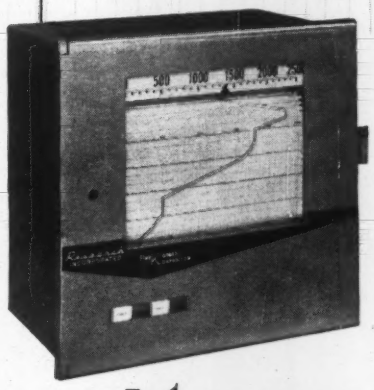
guided by a pencil-drawn curve

NO CAMS

and a

RECORDING CONTROLLER

which superimposes a record of actual process performance and applies corrective control when performance deviates from the plotted program



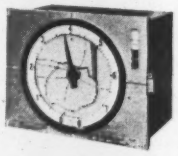
PREKORDER

TRADE-MARK

brings new flexibility to the automation of industrial process with closed-loop control.

1. **Pencil Programming** — No cams to cut.
2. **Superimposed Recording** — PreKorder's permanent record of process performance on a program chart overlay permits continuous visual comparison of record and chart.
3. **Programmed Limits** — To trigger alarm or shut-down circuits in case of process malfunction, just pencil allowable operating limits on the recording chart.
4. **Programmed Gain** — Varying the space between pencilled program lines varies the proportional control band or system gain.

Typical PreKorder applications are in programming temperature, pressure, power, load, flow, position, and other process variables. Both round and strip-chart models are available.



RI RESEARCH INCORPORATED

Write Dept. IC, Box 6164, Minneapolis 24, Minn.

CIRCLE 115 ON READER-SERVICE CARD

1 DIGITAL DISPLAY DOES THE WORK OF 15

NEW KEARFOTT DIGISTROBE* DISPLAY

Kearfott's new, highly compact Digistrobe digital display utilizes the stroboscopic principle to produce an exceptionally high-definition readout in the actual size shown here. Through the use of a unique shutter arrangement, a single diode-encoding matrix is shared by all columns (5 in the standard model), resulting in substantial savings in electronic components and circuitry. The fast response time of the Digistrobe (56 milliseconds transition from one five-digit quantity to a totally different one) permits a single unit to sample several different inputs on command through an input selector switch. Up to 15 individual displays of existing types can thus be replaced by a single Kearfott Digistrobe!

Incorporating only two moving parts and exclusively solid-state switching circuitry, the Digistrobe has extremely long life expectancy and requires minimum maintenance and service. Operation is directly from the output register of a computer, counter or allied equipment, eliminating the cost of intervening circuitry. Two years of extensive laboratory tests assure compliance with Kearfott's rigid standards of quality. For complete data and specifications, write for Digistrobe bulletin.

*Kearfott Trademark

GP

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

CIRCLE 116 ON READER-SERVICE CARD

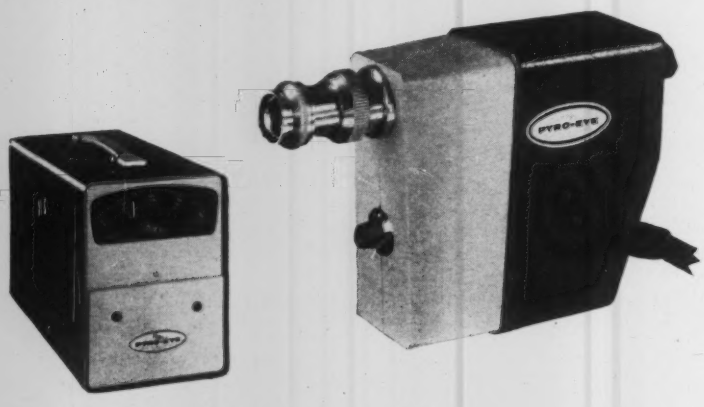
NEW...

PYRO-EYE*

Two-Color Optical Pyrometer

provides

fully automatic temperature measurement, recording and control in the ranges from 750°C to 2500°C and 1400°F to 4500°F.



Pyro-Eye is designed for in-plant and laboratory temperature measurement of incandescent molten metal, glass, ceramics, billets, rods, sheets, refractories and many other high temperature applications.

Continuous, automatic measurement and control of high temperatures is now possible because Pyro-Eye provides a high degree of repeatability and accuracy.

Pyro-Eye is accurate because it is relatively unaffected by unknown or variable emissivity. It measures temperature as a function of spectral characteristics . . . not as a function of total radiation.

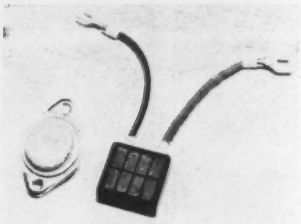
*Trade Mark of Instrument Development Laboratories, Inc.

For complete information write for brochure.

INSTRUMENT DEVELOPMENT LABORATORIES, INC.
Subsidiary of ROYAL McBEE
67 MECHANIC STREET, ATTLEBORO, MASS., U. S. A.

CIRCLE 117 ON READER-SERVICE CARD

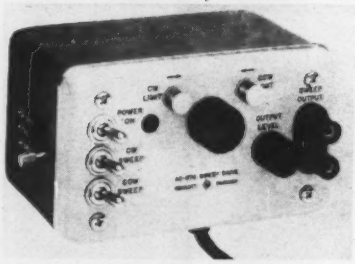
THERMOELECTRIC KIT



New experimental kit for study of thermoelectric principles contains F-8, 8-thermocouple Frigistor module; two fin assemblies, one for use at hot junction for heat dissipation, one for mounting transistors which require cooling; one Model F2 Neelium (new semiconductor material) thermocouple; heat-conductive adhesive, etc. (Picture compares module with germanium transistor.)—*General Thermoelectric Corp., Box 253, Princeton, N. J.*

CIRCLE 282 ON READER-SERVICE CARD

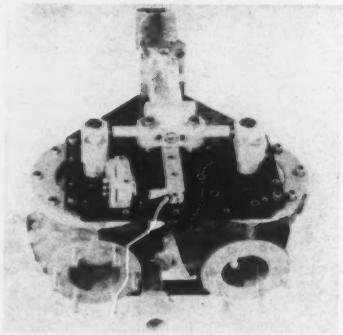
SWEEP DRIVE



New Model AC-97C Sweep Drive automatically sweeps oscillators and other tunable devices through frequency ranges. As accessory for Model 302A Wave Analyzer, it converts it to sweep oscillator-tuned voltmeter for automatic frequency response measurements, even in noisy systems. —*Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif.*

CIRCLE 283 ON READER-SERVICE CARD

DUAL PROPELLANT VALVE



New Flo-Ball Valve handles 12-000 lb liquid oxygen and ammonia per minute at full throttle and, with 4 other valves in first and second igniter stages, enables X-15 pilot to control engine, throttling from 25,-000 to 50,000 lb thrust.—*Hydromatics, Inc., 5 Lawrence St., Bloomfield, N. J.*

CIRCLE 284 ON READER-SERVICE CARD

The ASTRAGAUGE

Safe,
Accurate,
Easy Reading

For Pressures to 100,000 p.s.i.g.

prompt delivery

New 6" diameter gauge is available in 12 ranges from 1,000-100,000 p.s.i.g. Features: multiple turn 316 stainless steel Bourdon element for longer life and greater accuracy; dial readings spread over 300°; expendable diaphragm-type back to relieve internal pressure; safety plate in front of element; no welding or soldering used on element or socket.

Write for complete data and prices.

ASTRA CORPORATION
HATBORO, PA., OSborne 5-1652
CIRCLE 118 ON READER-SERVICE CARD

Now! a "Four-Ways Better" THERMOCOUPLE

Revolutionary design uses thin flat ribbon thermocouple wires and mica insulation of .0002 inches thickness. Operational under extremely high velocity and pressure conditions.

- √ 1. Response time of less than 10 microseconds!
- √ 2. Maximum continuous service temperature of over 2000°F!
- √ 3. Operating pressure range to 50,000 psi!
- √ 4. Sensing tip has unlimited life!

AVAILABLE IN ALL STANDARD THERMOCOUPLE ELEMENTS.

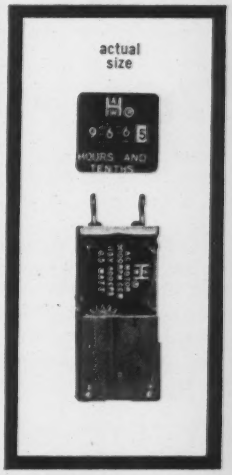
For complete details and data on other models write:

NANMAC CORPORATION
P.O. BOX 5 INDIAN HEAD, MARYLAND

CIRCLE 119 ON READER-SERVICE CARD

PLEASE DON'T SWALLOW OUR MOTOR

...IT'S HIDING BEHIND THE ASPIRIN. Actually, we set out to build an easy-to-read tiny timer... but we first had to build an aspirin-sized motor to drive it. This assignment might have been a headache for a sorcerer, but A. W. Haydon did it. And there is something magical about these micro-miniature elapsed time indicators and companion events counters. ■ This digital elapsed time indicator has many outstanding features: size is only ½" square x 1 1/16" long... weight .75 ounce...



meets all mil specs... temp. range −54 to +125°C... vibration to 2000 cps at 20 G... choice of two ranges (hours to 9999, tenths to 999.9)... power input .5 watt, max. In fact, the complete data outweighs the equipment. Send for our heavyweight literature on the 19200 ETI right now. ■ Electrical or electronic, the A. W. Haydon Company works wonders in time. For electronic requirements call Culver City. For electromechanical devices call on our wizards in Waterbury.

THE AWH HAYDON COMPANY
228 N. ELM ST., WATERBURY 20, CONNECTICUT
CIRCLE 120 ON READER-SERVICE CARD

READ

any surface temperature in 3 seconds with

Alnor PYROCON®

Particularly, in the lower temperature range, the Alnor Pyrocon has extreme accuracy unmatched by any other instrument of its type.

Alnor offers the widest variety of interchangeable tips for reading temperatures on metallic or non-metallic, flat, curved, revolving or stationary surfaces as well as semi fluid materials, plastics, liquids, molten or soft metals, dies, rubber, waxes and many other surface or subsurface materials.

The Pyrocon is a compact, rugged instrument built with the highest standards of accuracy and dependability as well as speed in reading.

Eight models with temperature ranges from 0—300° F. to 0—2000° F. Write for bulletin 4257.

Alnor INSTRUMENTS

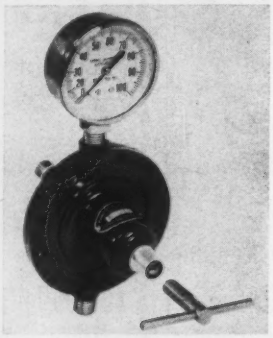
ALNOR INSTRUMENT CO.

Division of Illinois Testing Laboratories, Inc.

Room 518, 420 N. LaSalle St., Chicago 10, Illinois

CIRCLE 121 ON READER-SERVICE CARD

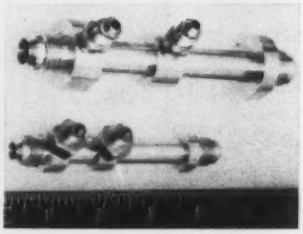
METERING LINE REGULATORS



New L-40-AR Series of Metering Regulators for common gases provide sensitive control, pass 0 to 100 cu ft/hr. All have ¼" pipe thread inlets to prevent accidental mounting in high pressure cylinders. Assure uniformity of gas control and prevent back pressure entering pipe.—*Harris Calorific Co., 5501 Cass Ave., Cleveland, Ohio.*

CIRCLE 285 ON READER-SERVICE CARD

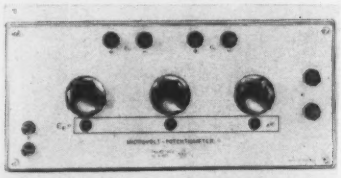
VENTURI FLOW METERS



New series of lightweight Venturi Flow Meters cover range of flow rates as low as 0.05 lb/min with standard inlet conditions. Aluminum or stainless, throat sizes from 0.1" to 4", standard AN end fittings for tube sizes from ⅜" to 3", standard pipe and V flange end fittings available. Available as precision calibration units or uncalibrated meters with calculated performance curves.—*Flow-Dyne Engineering, Box 9007, 1017 Norwood St., Fort Worth, Texas.*

CIRCLE 286 ON READER-SERVICE CARD

MICROVOLT POTENTIOMETER



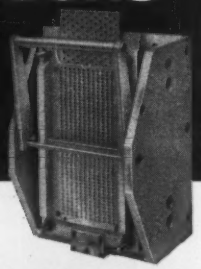
New Model AE5075 Microvolt Potentiometer features range from 0-1110 μv, resistance of 100 ohms/mv, built-in saturated standard cell power source, comparison accuracy of 1 μv or less depending on galvanometer sensitivity.—*Physics Research Labs., Box 555, Hempstead, N. Y.*

CIRCLE 287 ON READER-SERVICE CARD

TAURUS

PUNCHED CARD SENSORS

Reads Entire Punched Card Statically



FOR

Simple Switching Using Standard Punched Cards

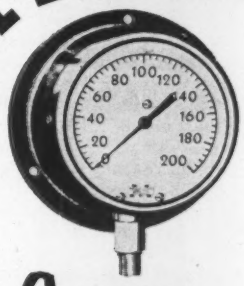
Taurus Punched Card Sensors statically read entire standard I.B.M. or Remington Rand punched cards.
Each hole position has a corresponding closed switch, and each unpunched hole position has a corresponding open switch when the Sensor is actuated. Used for Automatic Test Equipment and other automation devices.
Taurus also produces a complete line of Standoff and Feedthru Terminals insulated with Teflon*. *REG. T.M. OF E. I. DUPONT

Write for FREE Descriptive Literature

TAURUS Corporation
Academy Hill
LAMBERTVILLE, N.J.

CIRCLE 122 ON READER-SERVICE CARD

MARSHALLTOWN



Gauges

The right gauge for your specific needs

A complete line of gauges in stock available for early delivery. Gauges from 10-inches water pressure to 30,000 P.S.I. to meet your specifications on any equipment.

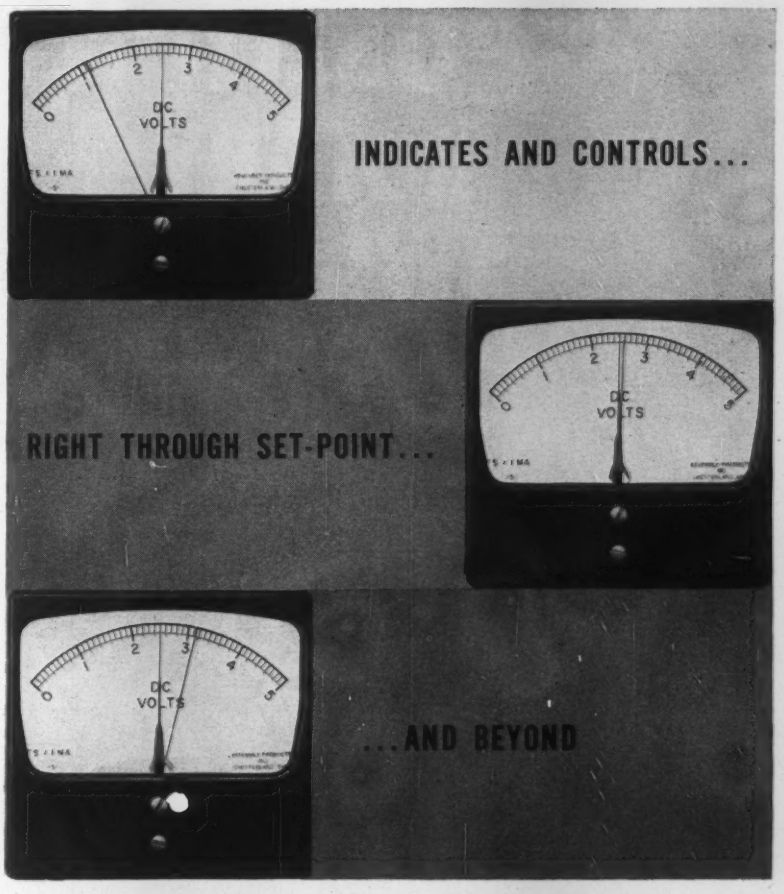
- Pressure
- Vacuum
- Compound
- Altitude
- Combination
- Diaphragm
- Hydraulic
- Special Purpose
- Dial Thermometer (Vapor Tension or Bi-Metal)

Let Marshalltown answer your gauge problems . . . write for information and prices.

MARSHALLTOWN MFG., INC.
A Subsidiary of The Electric Autolite Co.
MARSHALLTOWN, IOWA

CIRCLE 123 ON READER-SERVICE CARD

NEW—CONTINUOUS READING METER-RELAY



GIVES CONSTANT CONTROL

UPSCALE OR DOWN

API's new Continuous Reading Meter-Relay (CRMR) can do a diversity of control jobs for you. It will monitor and control just about any variable that can be translated to electrical values. It will handle low-level microamp or millivolt signals without amplification. In many applications, the CRMR's high sensitivity will permit simplification of control circuitry. In any application, it will give accurate (±2% or better), non-cyclic control.

The CRMR is simple. It consists of a D'Arsonval meter with toggle-mounted contacts; a load relay does the control switching. No signal-sampling interrupters are required. Reset is automatic and instantaneous.

Reliability? The CRMR is right now in service on such critical applications as monitoring radiation level.

Our Bulletin S-2-1 shows how the CRMR works, and gives full details on available ranges and prices. The latter, not incidentally, are a lot less than you might expect for so versatile an indicating control.

api **ASSEMBLY PRODUCTS, INC.**
Chesterland 10, Ohio

S.A. 2203

CIRCLE 124 ON READER-SERVICE CARD

8-POSITION ROTARY SWITCHES

for industrial and military applications

TYPE JL
Manufactured to MIL-S-21604 and BuShips drawing 9000-S6202-74422
TYPE AF
Manufactured to specification MIL-S-6807A and drawing #MS25002 (ASG)
TYPE A
for industrial applications.

ALL THESE SWITCHES are small units designed for tap, transfer, or selector use at low current ratings. The construction of the Esco Types AF and JL switches is the same as the Type A switch except that they are manufactured with materials to meet applicable MIL Specifications and BuShips drawings.

These switches provide unlimited rotation in both directions, or movement can be limited to any number of the eight positions.

Type	Sections	Positions	Poles	Contacts	Indexing	Mounting	Electrical Ratings interrupting
A	1 to 10	2 to 8	1 to 20	nonshorting or shorting	45°	panel threaded bushing	5 amp., 120 volts a-c
AF	1 to 6	2 to 8	1 to 6	nonshorting only	45°	panel threaded bushing	5 amperes, 120 v. a-c and 28 v. d-c
JL	1 to 10	2 to 8	1 to 20	nonshorting or shorting	45°	panel threaded bushing	5 amp., 120 volts a-c

WRITE FOR BULLETINS that contain complete details including dimension drawings, torques, weights, standard and special switching assemblies, photographs, and "How to Specify" information.

ESCO of WEYMOUTH
ELECTRO SWITCH CORP.
Weymouth (Boston 88), Massachusetts

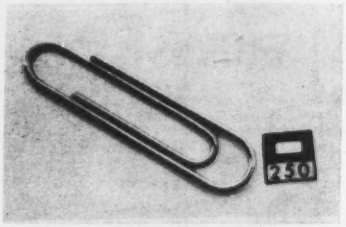
CIRCLE 125 ON READER-SERVICE CARD

INSTRUMENTATION RECORDER

New Model PS-303M 3-channel instrumentation magnetic-tape Recorder (2" x 4" x 5"; 31 oz including 7-oz tape) records dynamic data from 100 to 5000 cycles, unaffected by position or motion. Requires ¾ w supplied by standard mercury cells or other low-impedance power source; records 1 hr (min) at 1⅞ ips. Frequency response is flat within ±3 db from 100 to 5000 cps, with negligible flutter and wow; signal-to-noise ratio better than 30 db. —*Precision Instrument Co.*, 1011 *Commercial St., San Carlos, Calif.*

CIRCLE 288 ON READER-SERVICE CARD

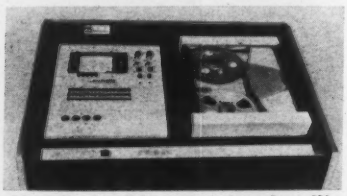
TEMP INDICATING LABEL



New ¼" x ¼" temperature indicating label, Model 200 Temp-Plate, for instrumenting transistors, miniature components, inaccessible machinery areas, etc. is ±1% accurate. Plastic tap sticks on surface, turns black when temp reaches desired value from 100°-500°F, provides absolute record of alarm-limit temp.—*Pyrodyne, Inc.*, 11973 *San Vicente Blvd., Los Angeles* 49, *Calif.*

CIRCLE 289 ON READER-SERVICE CARD

MOBILE DATA SYSTEM



New Radac I low-cost data handling system collects and prepares information directly for computers, eliminating need for large data processing installations. For use in automotive, processing, and manufacturing industries. Handles up to 48 analog inputs with ±10-μv resolution, ±0.1% accuracy.—*Radiation Inc., Melbourne and Orlando, Fla.*

CIRCLE 290 ON READER-SERVICE CARD

RESISTANCE THERMOMETERS *by* REC.....

−435 to +1800° F

Whether you are concerned with temperature measurements at −435° F or +1800° F there is a wide variety of REC temperature probes to fit your requirements. REC specializes in the design of high precision temperature probes, using highest purity platinum resistance elements.

Care and skill during manufacturing result in strain-free probes of highest stability.

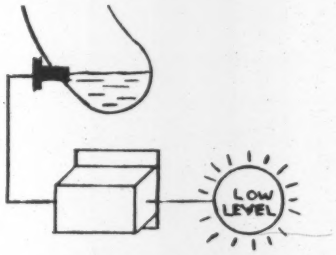
Write for New Catalog No. 66030 for further information on REC's many Temperature Probes, Pressure Transducers, Pitot-Static Tubes.

ROSEMOUNT ENGINEERING COMPANY

4900 WEST 78TH ST. MINNEAPOLIS 24, MINNESOTA

CIRCLE 126 ON READER-SERVICE CARD

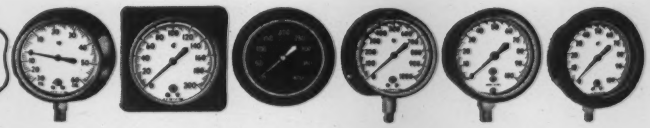
ULTRASONIC LEVEL CONTROL

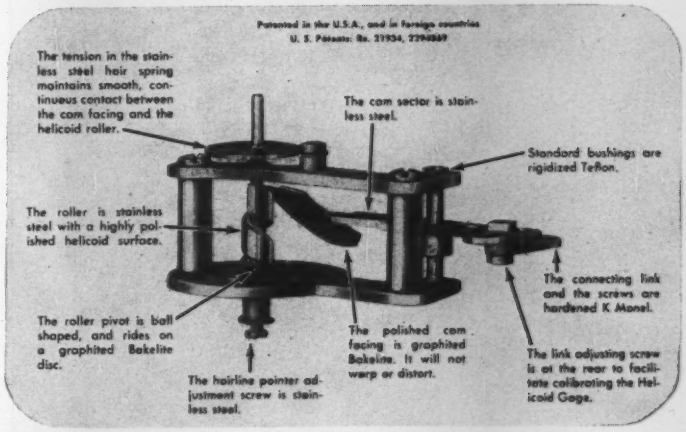


The basic SONOSWITCH system consists of a miniature ultrasonic probe and an ultrasonic controller which can be remotely positioned. The probe senses the presence or absence of liquid. The probe operates magnetostrictively such that the sensitive surface is vibrating at an ultrasonic frequency (40 kc) when exposed to air . . . The ultrasonic controller consists of a transistorized oscillator and a switching relay. Typical applications include leak detection, automatic tanking, level control, mixture valve positioning . . . (*From* 28 *page Bulletin, Powertron Ultrasonics Corp., Patterson Place, Roosevelt Field, Garden City, L. I., N. Y.*)

CIRCLE 329 ON READER-SERVICE CARD

ACCO Helicoid Gage U.S.A.




Patented in the U.S.A., and in foreign countries
U. S. Patents: Re. 21934, 2794869
The tension in the stainless steel hair spring maintains smooth, continuous contact between the cam facing and the helicoid roller.
The cam sector is stainless steel.
Standard bushings are rigidized Teflon.
The roller is stainless steel with a highly polished helicoid surface.
The connecting link and the screws are hardened K Monel.
The roller pivot is ball shaped, and rides on a graphited Bakelite disc.
The polished cam facing is graphited Bakelite. It will not warp or distort.
The link adjusting screw is at the rear to facilitate calibrating the Helicoid Gage.
The hairline pointer adjustment screw is stainless steel.

Exclusive Helicoid movement provides... *Sustained Accuracy... on the toughest jobs*

• Helicoid Gages have no gears, no teeth, reducing wear to an absolute minimum. No danger of fouling, either—rolling action of cam facing keeps contact surface clean. Helicoid Gages have been tested through 75,000,000 cycles, with virtually no wear or loss of accuracy, while conventional geared gages became useless after 500,000 cycles.

Helicoid Gages give *sustained* accuracy even when subjected to violent pressure pulsations or mechanical vibrations. Pointer can be set externally, without removing glass, and cannot be jarred out of position. Dial faces are easy to read, won't corrode or chip. A full range of Helicoid Gages is available for any application. Next time, specify Helicoid—the gage that *stays* accurate.

Bourdon Tubes won't Stretch, Leak, or Crack

Helicoid Bourdon tubes are made from seamless tubing, and are designed for maximum torque and minimum stress. At the factory, each tube is individually tested, overpressured, and stress relieved. Four materials—alloy steel, K Monel, stainless steel, and phosphor bronze—are available to meet applications ranging from tap water to almost any acid.

NEW! Solid-Front Safety Case Gives Added Protection

The new Helicoid solid-front case diverts the force of a burst in a backward direction, away from the operator. The force escapes by deforming, though not detaching, the back cover plate. Helicoid Gages are also available in phenol, acaloy flanged, acaloy flangeless, polished flangeless, round flush, polished flush ring, and square flush cases.

WRITE for details

Ask for Catalog DH-65

HELICOID GAGES

ACCO

Helicoid Gage Division • American Chain & Cable Company, Inc.

929-B Connecticut Ave., Bridgeport 2, Conn.

CIRCLE 128 ON READER-SERVICE CARD

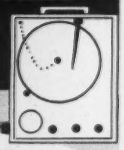
the timepiece with a 10-nanosecond tick

Does your system evaluation require a digital stop watch with a ten nanosecond tick? The Quantizer is your answer. The Series LFQ Quantizer by Computer Equipment Corp. enables you to measure and read out the elapsed time between two events or series of events with a resolution of ten nanoseconds—an order of magnitude better than previously available equipment. Sampling rate can be as high as 10^6 per second. ¶ The Quantizer forms the heart of Air Force sled velocity measuring systems which evaluate Minuteman and other important missile projects. Diamond Ordnance Fuse Labs, in conjunction with the Marshall Space Flight Center, will utilize the Quantizer to measure the altitude of the Pershing missile during test and operation phases. Perhaps the Quantizer can help you too. Write for more details, and include your output code format and other pertinent information.

QUANTIZER/COMPUTER EQUIPMENT CORP.

CIRCLE 129 ON READER-SERVICE CARD

Industrial Instruments Inc.
covers
THE WHOLE FIELD OF SOLUTION CONDUCTIVITY



from ULTRA PURE WATER *to* FUMING SULFURIC ACID

from REFRIGERANT BRINES *to* OVER 300°F

from HIGH VACUUM *to* 7500 PSI

from 1/100 ML SAMPLES *to* THE PACIFIC OCEAN

from BATTERY *to* LINE OPERATION

from 1/1000 CELL CONSTANT *to* OVER 1000/CM

from PLATINUM ELECTRODES *to* NO ELECTRODES

from D.C. *to* 20 KC

from SIMPLE LAB METERS *to* MULTIPOINT RECORDER CONTROLLERS

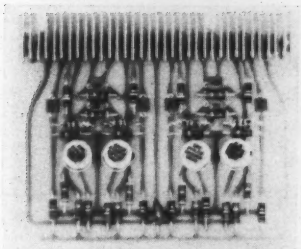
from POLISHED FILTRATES *to* THICK SLURRIES

Write for complete information on Solu Bridges, Solu Meters, Recorders, Larson-Lane Steam and Condensate Analyzers, Thallium Dissolved Oxygen Analyzers, Conductivity Cells and Accessories.

Industrial Instruments Inc.
89 Commerce Road. Cedar Grove. Essex County. N. J.

CIRCLE 130 ON READER-SERVICE CARD

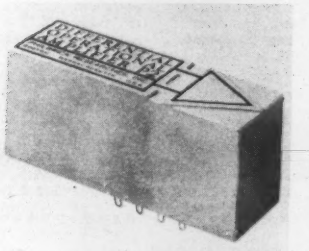
DIGITAL MODULES



New 200-kc Digital Modules, featuring two to four times circuit density of previous units, are contained on 4" x 4" glass-base printed-circuit cards incorporating Elco 35-pin connector. Four identical, independent flip-flops are on Model TF-101 unit; each includes set and reset diodes plus AND gates for use as binary counter or shift register. Other models available.—*Packard Bell Computer, Subs. Packard Bell Electronics,* 1905 *Armacost Ave., Los Angeles* 25, *Calif.*

CIRCLE 291 ON READER-SERVICE CARD

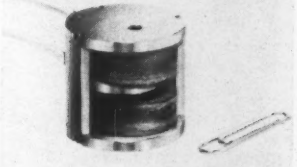
OPERATIONAL AMPLIFIER



New solid-state Differential Operational Amplifier, Model P2, contains no tubes or mechanical choppers; input is entirely "floating," yet has long term drift stability in sub-millivolt region. Typical input current well under 0.1 millimicroampere, allowing use in long time-constant integrating circuits using small polystyrene capacitors, or in electrometer-type amplifier circuits.—*George A. Philbrick Researches, Inc.,* 285 *Columbus Ave., Boston* 16. *Mass.*

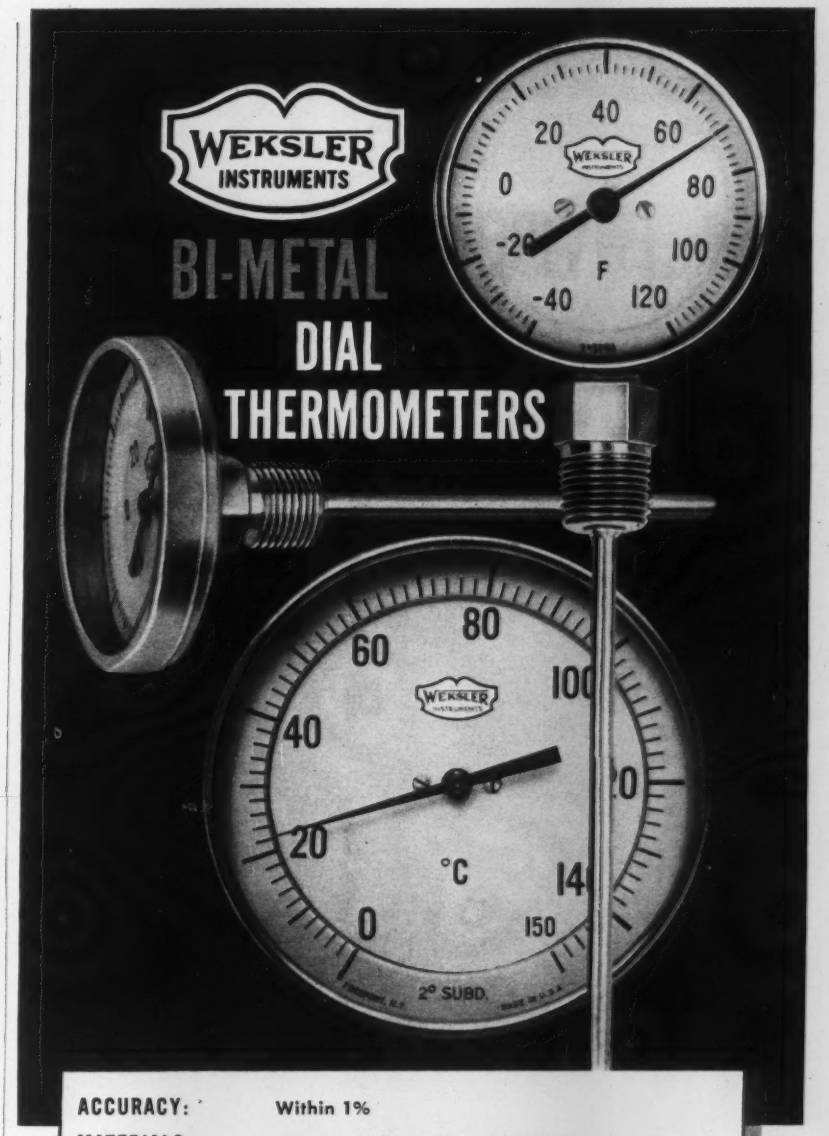
CIRCLE 292 ON READER-SERVICE CARD

PROPORTIONAL SOLENOID



New Model 10 series Proportional Solenoid is used in systems where permanent-magnet torque motor is not desirable, particularly at elevated temps to 450°F in contaminated environments. Units operate push-pull from quiescent current. Weight, 4 oz. —*Servotronics, Inc.,* 190 *Gruner Rd., Buffalo* 25, *N. Y.*

CIRCLE 293 ON READER-SERVICE CARD



ACCURACY:	**Within 1%**
MATERIALS:	**18-8 Stainless Steel, *welded* joints**
WORKMANSHIP:	**The finest, right through to *individual calibration***
COST:	**Being Weksler, cost is *always* moderate**

Weksler Bi-Metal Dial Thermometers are incomparable for every type of scientific temperature measurement. Dished anti-parallax dials, stem lengths to fit *all* standard thermo-wells, gasket sealed bezels, heavy crystal, *external* adjustment, and *all* standard F and C ranges are features you expect and get from Weksler!

WRITE FOR BULLETIN 700

WEKSLER INSTRUMENTS

"ORIGINATORS OF WORLD RENOWNED ADJUST-ANGLE THERMOMETERS"

WEKSLER INSTRUMENTS

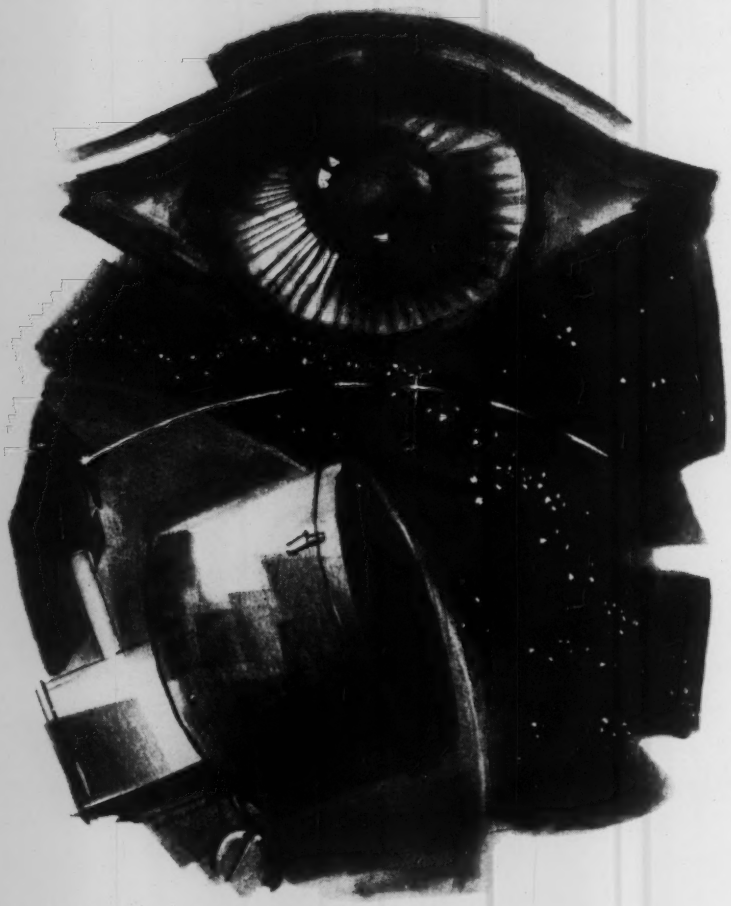
CORPORATION

195 EAST MERRICK ROAD, FREEPORT, L. I., N. Y.

Indicating and Recording Instruments for Temperature, Pressure and Humidity

CIRCLE 131 ON READER-SERVICE CARD

EXTENDING MAN'S SENSES IN HIS ENVIRONMENT AND BEYOND!



SIGHT

For many years, man has been extending his optical sensory perceptions which once extended only as far as his line of sight across the thousands of miles distance to celestial bodies by telescopes and other optical devices. Now in the new era of space, much new instrumentation is being developed for "seeing" what the eye can never see, and correlating it with other data for special purposes. A good example is the Franklin Systems Inc. flashing light recorder system now being used on the Atlantic Missile Range to "see" flashing lights on missiles miles away for time correlation between the light pulses and the range timing code.

FRANKLIN SYSTEMS
INCORPORATED
2734 HILLSBORO ROAD • WEST PALM BEACH, FLORIDA • TE 3-4602

CIRCLE 132 ON READER-SERVICE CARD

CRCA RESISTORS
FIXED • ADJUSTABLE
PRECISION • ULTRA-PRECISION

Ultimate Reliability: Unparalleled no rejects" record since 1953
Immediate Deliverability: .01% resistors are made to order in 24 hours.
Largest Selection: Hundreds of standard types and models.

PRODUCTS	CRCA BULLETIN #
Retohmeters*: Minute, Ultra-Precision User Adjusted Resistors	R-65
Plug-Trims* Plug-in Resistors and Socket Blocks for Divider, Decade or Trimmer Assemblies	R-55
Instruments: .0002% Voltage Dividers .01% Wheatstone Bridges .01% Resistance Decades	R-50
Banana-Plugs Resistors*: Axial, Radial, & One Sided Types, Also Jacks	R-44
R-Stacks*: Multi-Tap, Fixed and Adjustable Resistors and Dividers	R-40
Series "200's": Standard design Lug and Wire Lead Resistors	R-28

*Patents Applied For

For abbreviated performance data see specs below or EEM, 1960 edition, page 1263.

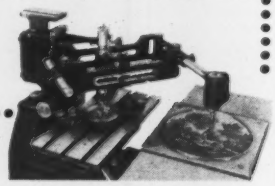
GENERAL RESISTOR SPECIFICATIONS

Type:	Wire-wound, also carbon and metal film.
Range:	.01 ohms thru 20 Megohms
Absolute accuracy:	1% thru .005% (at 25°C)
Relative accuracy:	thru .001%
Long term stability:	thru .001%
Temp. coefficient:	thru 2 ppm/°C.
Power dissipation:	thru 3 watts at 125°C.
MIL. Specs:	MIL-R-93A and MIL-R-9444 (applicable sections)
DELIVERY:	4 weeks regular, 1 week thru 24 hours—Special

CONSOLIDATED RESISTANCE COMPANY OF AMERICA, INC.
44 Prospect St., Yunkers, N.Y. YO 3-5900

CIRCLE 133 ON READER-SERVICE CARD

how to get
faithful 3-dimensional reproduction
in steel, other metals and plastics



Use the LOW COST precision-built Preis Panto 3D-5 Engraving Machine. Does both 2 and 3 dimensional engraving effortlessly.

- Reversible spindle for enlarging or reducing from a model, die or sample
- Precision ball bearings throughout.
- Reduction ratio range—1.6:1 to 7:1
- Four spindle speeds—7,000 to 18,000 RPM.
- Micrometer adjustment collar.
- Provided complete with floor stand and work tables.

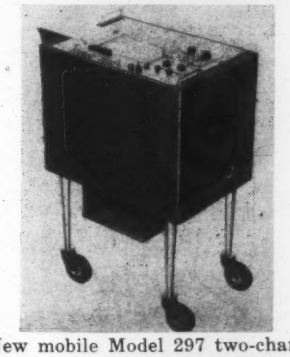
TRADE MARK PANTO

Write for complete details and prices. For immediate attention write directly to manufacturer below. Ask for nearest representative.

H. P. PREIS ENGRAVING MACHINE CO.
661 U. S. Highway 22, Hillside, N. J.

CIRCLE 134 ON READER-SERVICE CARD

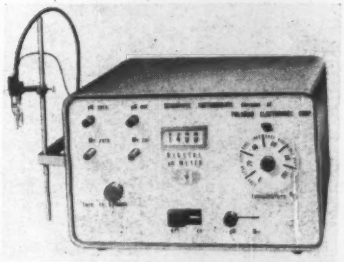
MOBILE OSCILLOGRAPH



New mobile Model 297 two-channel oscillograph uses plug-in interchangeable "850" style preamplifiers, is housed in 35" high wheel-mounted grey steel cabinet. Frequency response to 125 cps, within 3 db at 10-mm peak-to-peak amplitude; gain stability better than 1% over 20°C temp changes and 20-v power line variations; max non-linearity 0.25 mm.—*Sanborn Co., Industrial Div., 175 Wyman St., Waltham 54, Mass.*

CIRCLE 294 ON READER-SERVICE CARD

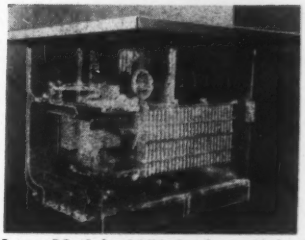
DIGITAL pH METER



New automatic self-balancing pH Meter is line operated, provides 4-digit readout. Covers range of 0-14.00 pH units, accurate to 0.02 units, not affected by line fluctuations to 10%. Has mv scale, accommodates any type of electrode.—*Scientific Instruments Div., Polarad Electronics Corp., 43-20 34 St., Long Island City 1, N. Y.*

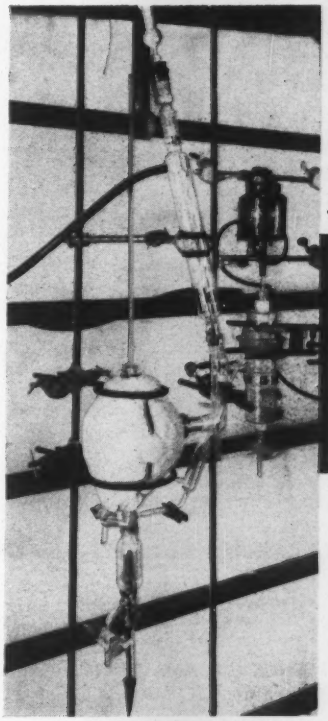
CIRCLE 295 ON READER-SERVICE CARD

DC POWER SUPPLY



New Model 2350-8 for dielectric testing of cables and klystron apparatus, for particle accelerators, and study of high-voltage discharges has output range to 350,000 v. Provides continuous 8-ma current at any output voltage.—*Sorensen & Company, Inc., Richards Ave., South Norwalk, Conn.*

CIRCLE 296 ON READER-SERVICE CARD



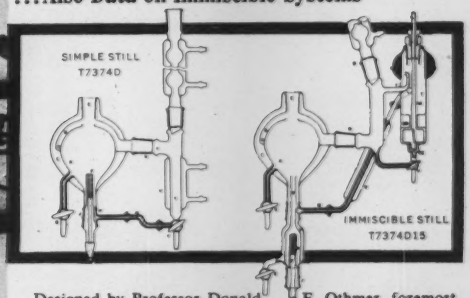
EXPERIMENTAL SET-UP OF IMMISCIBLE STILL

Revolutionary New

Vapor-Liquid Equilibrium Still

Provides Adiabatic Operation!

...Also Data on Immiscible Systems



Designed by Professor Donald F. Othmer, foremost authority on equilibrium stills, this new apparatus provides the ultimate in vapor-liquid equilibrium determinations. Integral arrangement of vapor jacket, alembic, and vacuum envelope minimizes heat losses and condensation and rectification of contacting vapors. Dead-spot-free vapor jacket surrounds upper portion of still pot. Vacuum envelope, silvered except for a narrow observation strip front-and-back, and evacuated to a pressure below 1 micron, surrounds entire pot.

Adaptations for partially miscible systems, Cottrell boiling and flash vaporizing enable still to be used for rapid determination of vapor-liquid equilibria on a wide variety of systems.

**Othmer, D. F., Gilmont, R. and Conti, J. J. Ind. Eng. Chem. 52, 625 (1960) Reprints furnished on request.*

PRICE LIST | T7374D ..... Simple Still $345.00
T7374D15 .. Immiscible Still $490.00

The EMIL GREINER Co.

20-26 N. Moore St., Dept. 423, New York 13, N. Y.

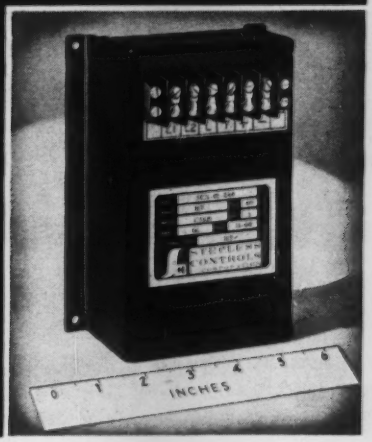
CIRCLE 135 ON READER-SERVICE CARD

"STEPLESS" TAKES THE FIRST STEP!

A MAJOR IMPROVEMENT IN TEMPERATURE CONTROL FOR FURNACES

PROPORTIONAL CONTROL OVER FULL RANGE OF FURNACE LOAD WITH SOLID STATE SWITCHING USING SILICON CONTROLLED RECTIFIERS.

- REPLACES SATURABLE CORE REACTOR AND MAGNETIC AMPLIFIER SYSTEM
- NO MORE DESIGN LIMITATION DUE TO NEED FOR MATCHING LOADS
- ELIMINATES COSTLY CONTACTOR FAILURE PROBLEMS



Stepless Control's Power-Prop® is basically a power input control that will operate from any pyrometer with a proportioning D.C. voltage output signal.

Available from stock for up to 75 Amps and up to 230 Volts A.C.

BTU Engineering Corporation, Waltham, Mass., has utilized these units successfully for the past 2 years in furnaces for the semiconductor industry.

STEPLESS CONTROLS CORPORATION
WALTHAM 54, MASS.

CIRCLE 136 ON READER-SERVICE CARD

LOW BUDGET...

GOW-MAC RESISTANCE FILAMENTS

...FOR FAST DELIVERY

METAL	FORM	Nominal Resistance: COLD	OHMIC	Current in Air at Room Temp. (Milliamps D.C.)
TUNGSTEN, BARE WIRE	HELIX	20	30	150
TUNGSTEN, GOLD PLATED	HELIX	18	27	150
TUNGSTEN, TEFLON CLAD For Chlorine and Fluorine Bearing Samples	HELIX	23	34	180
KOVAR (ALLOY OF NICKEL, COBALT, IRON)	STRAIGHT	5	8	200

NOTES:
(1) 12" Leads are .030 Kovar wire, silver soldered and insulated with fiber glass sleeve.
(2) Teflon clad tungsten helix is coated to a maximum of .005 inch. Melting point of coating is approximate 250°C (482 F).

For use with corrosive gases or where vibration or shock are present.
Response time is increased because of greater filament mass; signal strength is diminished except where current (filament temperature) can be increased.

ALSO AVAILABLE:
- Thermal Conductivity Cells for Gas Analysis
- Micro-Cell for use with ¼" Packed Columns, VPC
- Gas Blenders for Automatic Mixing of Gases
- Temperature Regulated Cells
- Gas Density Detectors for VPC
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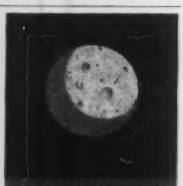
GAS ANALYSIS BY THERMAL CONDUCTIVITY SINCE 1935

CIRCLE 137 ON READER-SERVICE CARD

PRESSURE CALIBRATION LABORATORY



A NEW RUSKA SERVICE

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The Ruska Calibration Laboratory offers to industry the extraordinary precision of calibration long associated with the Ruska Dead Weight Gage. Facilities are designed to calibrate pressure measuring devices by direct comparison with instruments calibrated by the National Bureau of Standards.

Write for complete literature.

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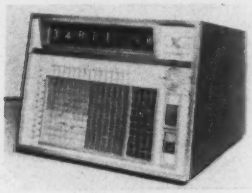
CIRCLE 138 ON READER-SERVICE CARD

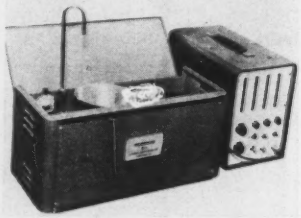
TELEMETERING SYSTEM



New solid-state telemetering and supervisory control system, RATE (Remote Automatic Telemetering Equipment), performs data gathering, constant alarm-scanning and control over one low-grade communications link. Eliminates multi-channel systems; serves up to 1200 points. Compatable with on-line computer control systems.—*Shand and Jurs Co., Subs. General Precision Equipment Corp., 2600 Eighth St., Berkeley 10, Calif.*

CIRCL 297 ON READER-SERVICE CARD

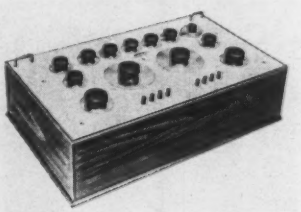
FLOWRATE COMPARATOR



New Flowrate Comparator compares, calibrates, and checks accuracy of orifice, rotameter and turbine type liquid flowmeters with flow rates from 0-800 lb/hr. Operates on dynamic weighing principle; electronically times flow of known weight of liquid. Over-all accuracy ±0.25%; sensitivity 0.0215%; inertia compensated.—*Simmonds Precision Products, Inc., 105 White Plains Rd., Tarrytown, N. Y.*

CIRCLE 298 ON READER-SERVICE CARD

DC POTENTIOMETER



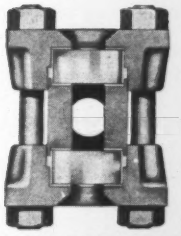
New Type 9144 4-dial, 6-figure, dual range (x 1; x 0.1) DC Vernier Potentiometer measures to 2.101010 v, is "self checking." Uses include: resistance comparator accurate to 2 ppm, saturated standard cell comparator (detects differences of 1 μv), constant temp enclosure (air-thermostated, contains 2 internal saturated standard cells).—*Sensitive Research Instrument Corp., 310 Main St., New Rochelle, N. Y.*

CIRCLE 299 ON READER-SERVICE CARD

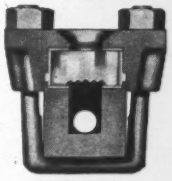
Strahman

HIGH PRESSURE GAUGES

USED IN
REFINERIES
AND
CHEMICAL PLANTS
THROUGHOUT
THE WORLD



THRU VISION



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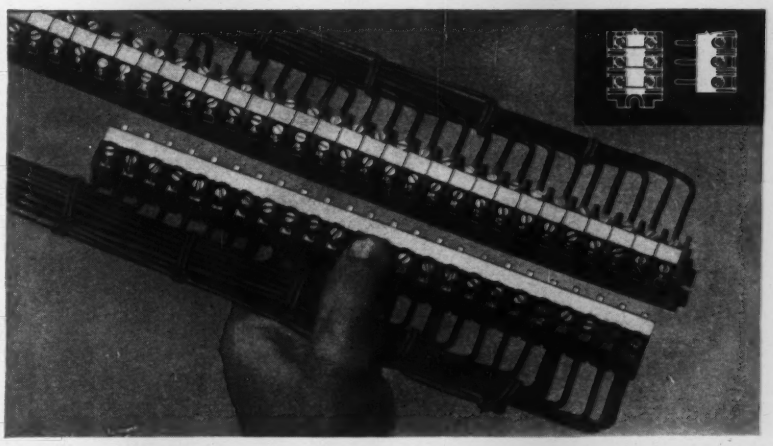

If It's Quick Handling of Circuit Groups You Want...

Buchanan has it. . . . Circuit groups are wired to Buchanan Fanning Strips made especially for Buchanan sectional MD pres-SURE-blocks. You connect and disconnect from 2 to 24 circuits without handling individual wires and the possibility of wiring errors. There's no end to the versatility of MD blocks. Just 2 different snap-fit parts build any length block. Common wires —equal to 1 #22 thru 1 #8—can be grouped under a single tubular contact. That saves space, minimizes jumpering, eliminates lugging. Write now for Bulletin IC-2.

Tubular contacts listed by UL. Blocks listed for 600 v. by CSA.

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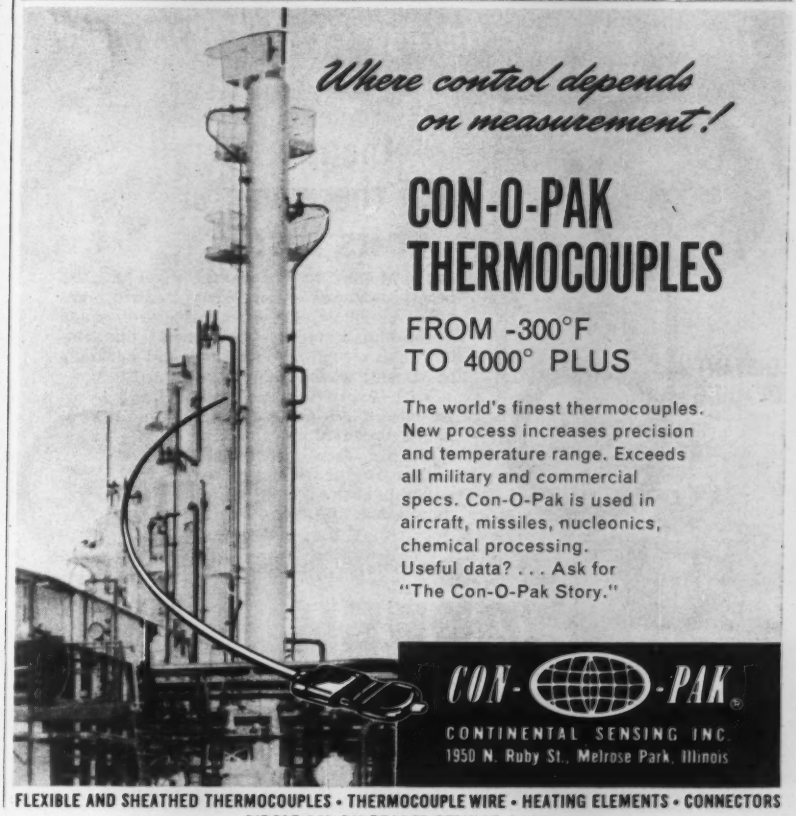
In Canada: ESNA CANADA LIMITED, Toronto 16

CIRCLE 144 ON READER-SERVICE CARD



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CON-O-PAK THERMOCOUPLES

FROM -300°F
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The world's finest thermocouples. New process increases precision and temperature range. Exceeds all military and commercial specs. Con-O-Pak is used in aircraft, missiles, nucleonics, chemical processing. Useful data? . . . Ask for "The Con-O-Pak Story."

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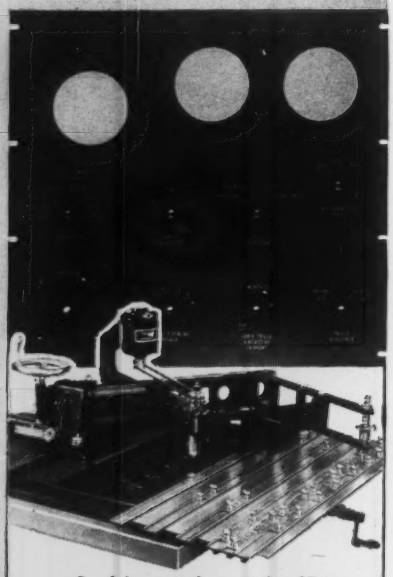
FLEXIBLE AND SHEATHED THERMOCOUPLES • THERMOCOUPLE WIRE • HEATING ELEMENTS • CONNECTORS

CIRCLE 141 ON READER-SERVICE CARD

any size panels

engraved in your own plant



Engrave 1-inch nameplates or 6-foot panels by unskilled labor.

Spindle covers 18¼" x 6" in one set-up — more than any other machine of its kind.

Bench type model I-R—$685.

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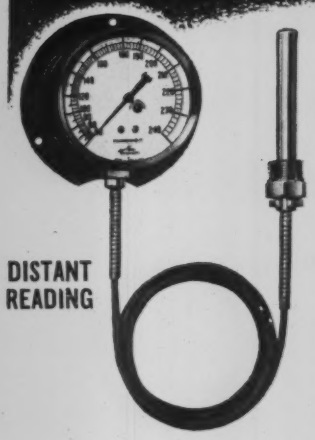
154 WEST 14th STREET, NEW YORK 11, N. Y. IN CANADA: 359 St. James Street West, Montreal, P. Q.

CIRCLE 192 ON READER-SERVICE CARD

There's a MARSH thermometer for every need



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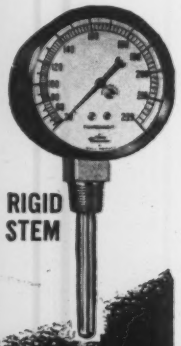
the dial thermometer at its best

In the Marsh Dial Thermometer you have the best type—the bourdon tube type—in its highest development. These are instruments made in the Marsh manner—instruments that embody the recognized precision and accuracy of Marsh Pressure Gauges.

Both vapor-tension and gas-filled types are available in the broad Marsh line...a type, size, case-style, finish and temperature range to solve practically any dial thermometer problem.



RIGID STEM

Ask for the Thermometer Catalog

MARSH

MARSH INSTRUMENT COMPANY, Dept. 42, Skokie, Ill.
Division of Colorado Oil & Gas Corporation
Marsh Instrument & Valve Co., (Canada) Ltd.
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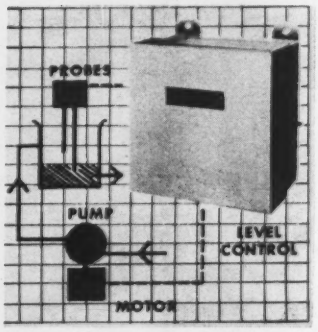
Houston Branch Plant, 1121 Rothwell St.
Sect. 15, Houston, Texas

CIRCLE 193 ON READER-SERVICE CARD

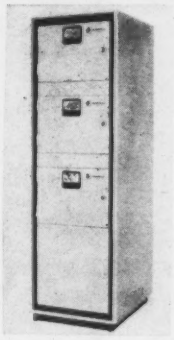
LEVEL CONTROL



New electrode-type, transistorized Level Control so sensitive that distilled or deionized water completes 15-μamp circuit through probes, has single point control, or differential level control with probes at different levels; sensitivity adjustment for liquids of various conductivity; and thermistor compensation to cancel effects of rising ambients. No moving parts contact liquid, no floats to clog or jam, no tubes or batteries to replace. Weather-tight control unit has 15-amp SPDT relay, may be remotely located.—*Precision Thermometer & Instrument Co.*, 1434 *Brandywine St., Phila.* 30, *Pa.*

CIRCLE 300 ON READER-SERVICE CARD

AC POWER REGULATOR

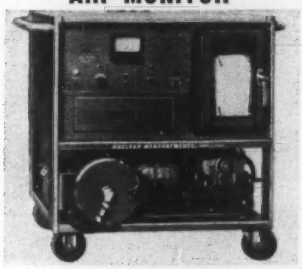


New 3-phase, 630-kva Regulator features absence of power factor, instant response, and smooth proportional power regulation from 5% to 95% of full power for electric furnace control or for heavy a-c power loads. Uses ignitrons for stepless regulation, accepts either a-c or d-c control signals. Rated output is 450 amp in each phase at 230, 460, or 600 v; tolerates overloads to 100% for 5 min.—*Research, Inc., Box* 6164, *Minneapolis* 24, *Minn.*

CIRCLE 301 ON READER-SERVICE CARD

FOR MORE INFORMATION ON ANY NEW PRODUCT, USE POSTAGE-FREE INQUIRY CARD ON PAGE 368

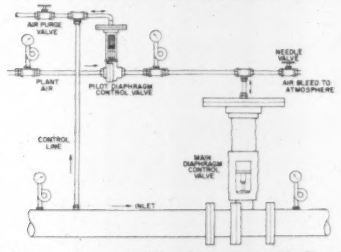
AIR MONITOR



New AM-2S Air Monitor detects gamma radiation within 0.33-0.55 mev in air-borne iodine vapors, protects personnel working near reactors. Unit can be set for other gamma emitters for any energy range. Iodine activity of vapors deposited on activated carbon filters sets off warning bell and light at determined level. —*Nuclear Measurements Corp.*, 2460 *N. Arlington Ave., Indianapolis* 18, *Ind.*

CIRCLE 302 ON READER-SERVICE CARD

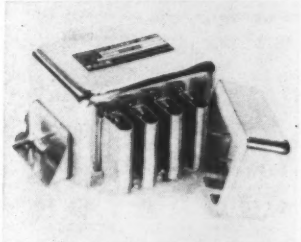
BACK PRESSURE REGULATORS



New 4″ and 6″ air-operated Back Pressure Regulators have capacities to 50,000-lb steam per hour or 25,000 gpm water. Sliding gate seats in pilot and main valve give accurate regulation, tight shut-off and minimum maintenance. Suitable for pressures to 250 psi wsp and temps to 500°F. Bulletin SRBc 75-60.—*OPW-Jordan*, 6013 *Wiehe Rd., Cincinnati* 13, *Ohio.*

CIRCLE 303 ON READER-SERVICE CARD

TC REFERENCE JUNCTION



New Series FRJ Thermocouple Reference Junction for in-flight applications operates on 105-125 v, 380-420 cps, from —65° to 165°F with less than ½°F reference temp variation. Units available with up to 24 channels, any junction temp from 25°F above ambient to 250°F as specified. Uniformity and stability for long unattended operation within ±⅛°F.—*Pace Engineering Co.*, 13035 *Saticoy St., N. Hollywood, Calif.*

CIRCLE 304 ON READER-SERVICE CARD

- PRIMARY PRESSURE STANDARD
- mercurial BAROMETERS
- precision MANOMETERS
- PRESSURE CONTROLLERS

The Finest Instruments of Their Kind in the World!

√ MICROMETER STANDARD BAROMETER
Type MS-2, Primary Pressure Standard, Accuracy .001" RMS
Ranges: 0-31", 0-62", 0-100" Hg.

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√ PHOTO SCANNER, Type PSR-1
Micro Reading (.0001"), pressure deviation signal, Accessory for Type A-1 Barometers and Manometers

√ PRESSURE CONTROLLER, Type PSC-2
Servo + Manual operation for automatic setting and holding pressures to within +.0005" Hg.

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Manual operation for manual setting and holding pressures to within +.001" Hg.

For special problems or more information write:
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Precision Pressure Standards and Controls
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CIRCLE 140 ON READER-SERVICE CARD

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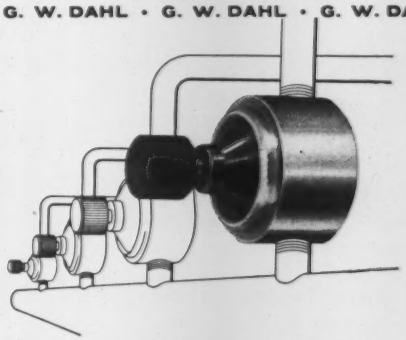
LOW COST MINIATURE VALVE FOR TIGHT SHUT-OFF!



Dahl FLEXI-PHRAGM packless diaphragm valve ideal for instrument air and other gas and liquid services . . . for isolating and/or testing the pneumatic circuit in process control loops.

Resilient diaphragms (Neoprene, Viton A or Buna) withstand deformation by slurries, trapped impurities (unfiltered service) . . . still provide positive shut-off. Diaphragms resume original configuration when valve is opened and particles washed away . . . even after prolonged closures.

Rated to 500 psig and 180°F. Closing torque only 10 lb.-in. (as rated) in dead end service. Brass bodies with ⅛″ or ¼″ NPT connections. Panel mounts available.

REQUEST complete data on this low cost, high performance valve. G. W. Dahl Co., Inc., 82 Tupelo St., Bristol, R. I.

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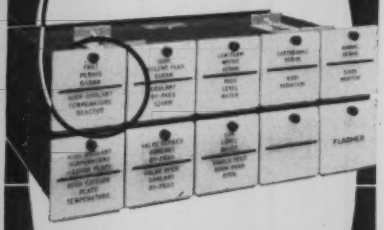

with new MAGNA-PLAC nameplates

Two complete alarm points in each cabinet position conserve panel area and reduce system cost.

- Nearly 5 sq. inches of engraving area for *each* point
- AO and AF sequences standard
- Conforms to regular De-Line construction features & quality
- All plug-in units are hermetically sealed

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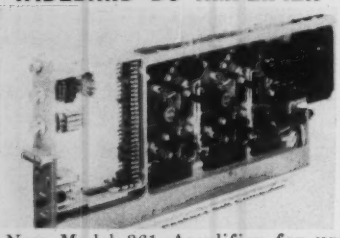
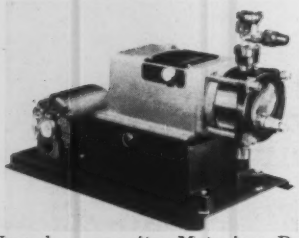
WIDEBAND DC AMPLIFIER



New Model 361 Amplifier for use with interchangeable plug-in input circuit modules has 100-kc bandwidth unaffected by gain changes. Common-mode rejection ratio increases directly with amplifier gain; is 1,000,000 between dc and 150 cps. Input impedance at dc is 1000 megohms (min). —*Packard Bell Computer, Subs. Packard Bell Electronics,* 1905 *Armacost, Los Angeles* 25, *Calif.*

CIRCLE 305 ON READER-SERVICE CARD

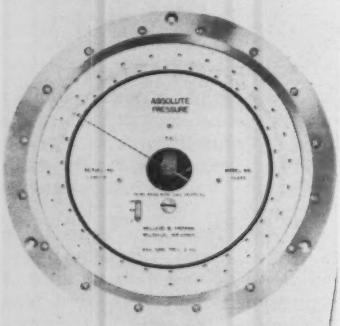
METERING PUMP



New low-capacity Metering Pump has single head (Series A-747, shown) or double heads (Series A-748). Max capacities are 250 and 500 gpd, respectively; max pressure 100 psi for both. Dual-head model has separate stroke-length adjustment and indication for each head, proportions 2 chemicals simultaneously, or handles twice volume of single model with one pump.—*Wallace & Tiernan Inc.,* 25 *Main St., Belleville* 9, *N. J.*

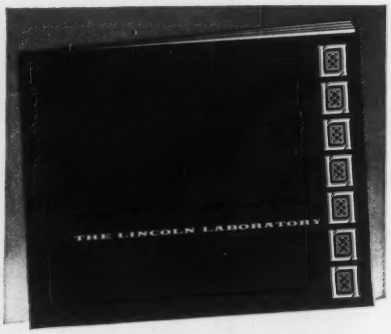
CIRCLE 306 ON READER-SERVICE CARD

BOURDON TUBE GAGE



New ratio linkage design of Bourdon Tube Gages enables pressure readings to 500 psi. Ni-Span-C tubes assure accuracy of 0.1% of full scale range; small-volume, Hi-Span-C tubes are corrosion resistant to variety of gases.—*Wallace & Tiernan Inc.,* 25 *Main St., Belleville* 9, *N. J.*

CIRCLE 307 ON READER-SERVICE CARD



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We urgently request the participation of senior members of the scientific community in our programs in:

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NEW RADAR TECHNIQUES

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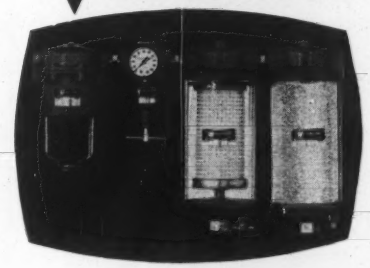
BOX 35

LEXINGTON 73, MASSACHUSETTS

NEW DEHYDRATOR

for "instrument-pure" compressed air.

The WILKERSON "Chem-Guard" package provides micro-clean, dehydrated, oil-free air *only where needed.*



NEW EXCLUSIVE FEATURES

★ **LOWEST PRICE** for package, application and installation. No electrical water or sewer connections needed.

★ **DEPENDABILITY** of the "Chem-Guard" dehydrator assured because of no moving or mechanical parts.

★ **SIMPLIFIED, ECONOMICAL, SERVICING**—No draining or reactivation is necessary. Exact amount of replacement chemicals available in vacuum packed cans.

★ **BUILT-IN VISIBLE INDICATOR** shows color change when servicing is required.

Choose the non-corrosive chemical to suit your needs

(a) reduce dew point to —65°F or
(b) reduce dew point to —100°F or
(c) remove traces of oil to 20 parts per million.

WRITE TODAY for complete information on the NEW "Chem-Guard".

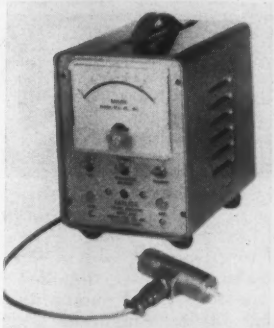
WILKERSON CORPORATION

Dedicated to keeping the NEW in pNEUmatics

1619 W. Mansfield, Englewood, Colo.

CIRCLE 147 ON READER-SERVICE CARD

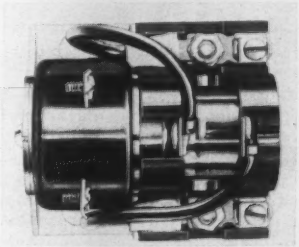
TORQUE INDICATOR



New Torque Indicator system furnishes stabilized excitation for transducer and direct reading on panel meter. Approx 1-v d-c output full scale for recording and control; accuracy within 2%, no noise, and infinite resolution. Available in ranges from 0.1 to 100,000 in-lb and 0 to 80,000 rpm.—*Kavlico Div., Vinson Manufacturing Co., 8044 Woodley Ave., Van Nuys, Calif.*

CIRCLE 308 ON READER-SERVICE CARD

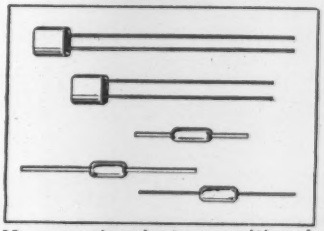
MERCURY RELAY



New Series W-20-3 plunger-type mercury Relay for heavy duty loads has one moving part, provides millions of operations with speeds to 100 makes or breaks per minute at rated load. Two keyhole slots for mounting. Coils available for 24, 120, 240, and 440 v ac. Bulletin 0-20.—*Mercoid Corp., 4201 Belmont Ave., Chicago 41, Ill.*

CIRCLE 309 ON READER-SERVICE CARD

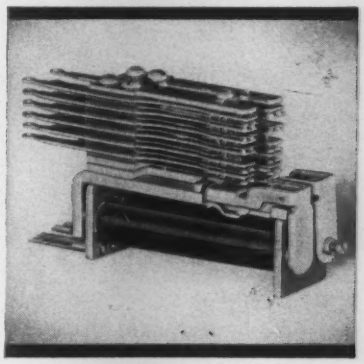
SEMICONDUCTOR TEMP SENSORS



New semiconductor positive-slope temperature Semitemp Sensors for manufacturers of amplifiers, power supplies, servos, etc. provide temp coefficient of 0.8%/°C. Effective range of −60° to 150°C. Standard ohmages within 100-2,000 ohm range; tolerance of ±10%.—*Kulite Semiconductor Products, Inc., 1030 Hoyt Ave., Ridgefield, N. J.*

CIRCLE 310 ON READER-SERVICE CARD

Relays by Stromberg-Carlson



Telephone-type quality • reliability durability

If you require reliable, durable, top quality relays in the equipment you manufacture, you're well advised to consider the relays made by Stromberg-Carlson.

Hundreds of companies have found here the advantages based on our over sixty years of specialization in providing equipment and parts to the independent telephone world.

What's more, we go beyond just the manufacture of relays. If you desire, we can also provide wired mounting assemblies.

Our relays are available in a wide range of types, of which these are representative:

TYPE A: general-purpose. Up to 20 Form "A" spring combinations.

TYPE B: gang-type. Up to 60 Form "A" spring combinations.

TYPE BB: up to 100 Form "A" springs.

TYPE C: (illustrated) two on one frame. Ideal where space is tight.

TYPE E: characteristics of Type A, plus universal mounting. Interchangeable with other makes.

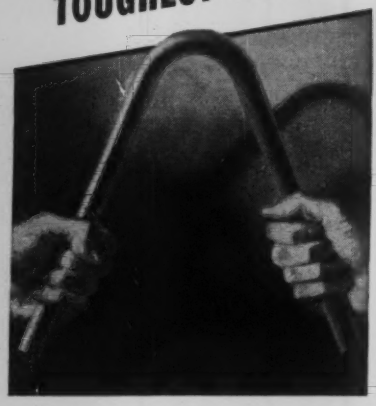
Types A, B, and E are available in high-voltage models. Our assembly know-how is available to guide you in your specific application.

Details on request from these Stromberg-Carlson offices: Atlanta—750 Ponce de Leon Place N.E.; Chicago—564 W. Adams Street; Kansas City (Mo.)—2017 Grand Avenue; Rochester—1040 University Avenue; San Francisco—1805 Rollins Road.

STROMBERG-CARLSON
A DIVISION OF
GENERAL DYNAMICS

CIRCLE 148 ON READER-SERVICE CARD

TUBING THAT KEEPS ITS TEMPER IN THE TOUGHEST SPOTS



PRECISION TUBING

Made To Your Product Requirements . . . Sold At Regular Prices

The right temper in tubing can mean the difference in finished product quality. It should be varied to meet the job to be done.

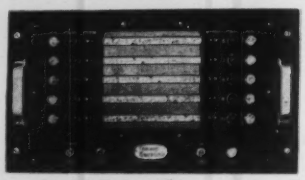
Precision Tubing can be produced to meet your most exacting specifications from annealed to full hard. Continuous hydrogen atmosphere and combusted gas atmosphere bright annealing furnaces, scientifically controlled by advanced instrumentation assures the correct temper in every foot of tubing . . . locked in for the life of the tubing.

Precise temper is only one of the outstanding qualities of Precision Tubing. Accuracy, mirror-finishes, quick deliveries and regular mill prices are all offered in Precision Tubing . . . in copper, brass, bronze, nickel, nickel-alloy . . . sizes .010" to 1.125" O.D. in all shapes. Get the full details, write for catalog to

PRECISION TUBE CO., INC.
North Wales, Pa.

CIRCLE 149 ON READER-SERVICE CARD

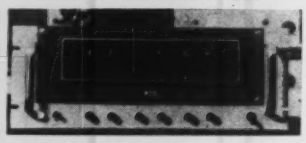
MULTI-POINT CONTROLLER



New Multi-Point Temperature Controller provides accurate (0.5% of range) automatic 2-position control for up to 10 processes. Also used as single-point controller, 5-point 3-position controller, and manual-balance indicator. Unit combines sensitive null-balance potentiometer measuring circuit with electronic control system; adapts to installations requiring off-on control; std scanning rate, 3 sec/pt.—*Thermo Electric Co., Inc., Saddle Brook, N. J.*

CIRCLE 311 ON READER-SERVICE CARD

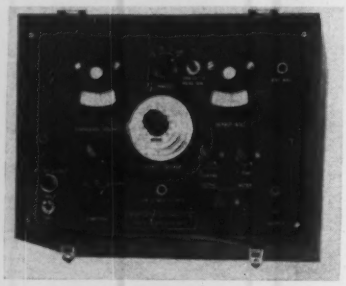
TIME GENERATOR



New Model 320 electronic digital Time Generator for system control and synchronization, or for time correlation among diverse data-acquisition and logging devices, employs 1-kc tuning-fork oscillator to assure 0.005% time-base accuracy. Provides timing markers at 0.001, 0.01, 0.1, and 1 sec intervals. Decimal outputs to total of 23 hr, 59 min, 59 sec provided at rear-panel connector, are simultaneously displayed on 6 inline glow-tube decimal indicators (Nixies).—*Technology Div., Lockheed Electronics Co., Box 446, Metuchen, N. J.*

CIRCLE 312 ON READER-SERVICE CARD

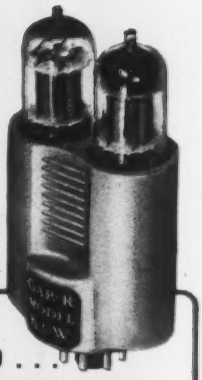
INCREMENTAL MULTIMETER



New Tensor 5880 Incremental Multimeter expands increments of any range about any point in range for display on external servo recorder; consists of Simpson 270 Multimeter with suppressor power supply and attenuator attached. Has over 50 values of current, voltage, resistance, audio power, temperature, and transistor characteristics. Typical accuracies are 1.5% dc and 2% ac.—*Tensor Electric Development Co., Inc., 1873 Eastern Parkway, Brooklyn 33, N. Y.*

CIRCLE 313 ON READER-SERVICE CARD

A familiar shape to DC amplifier devotees



WIDELY RECOGNIZED . . . WIDELY ACCEPTED . . . K2 OCTAL PLUG-INS FROM PHILBRICK

FAST DC: K2-W is an efficient, foolproof high-gain operational unit for all feedback applications, fast and slow. The K2-W features balanced differential inputs for low drift, high input impedance, low output impedance, and economy of operation. Its range of operation is from d-c to above 100 kc depending on external circuitry. **$24***

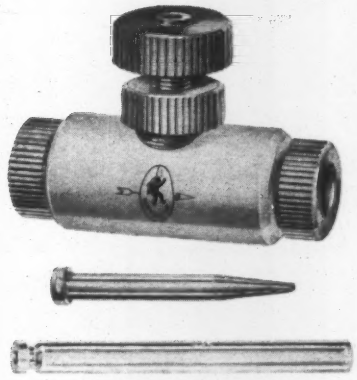
SLOW DC: K2-P gives to other dc amplifiers, such as K2-W and K2-XA, drift stability well under 1 millivolt, long term. This chopper stabilized unit has the same case structure and octal base as the K2-W and sells for **$60***

HOT DC: K2-XA, a new amplifier of improved reliability, is primarily useful in operational circuits where an output voltage range from minus to plus 100v (at 3 milliamperes) is required. Its pass band extends to beyond 250 kc depending on external circuitry. **$28***

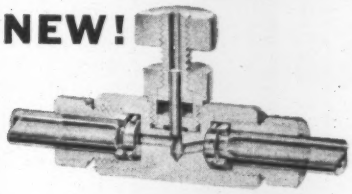
* • Military equivalents available
• OEM's: write wire or phone for quantity prices
• 24 page Applications Manual available on request

GEORGE A.
PHILBRICK
RESEARCHES, INC.
127 Clarendon St., Boston 16, Mass.
COmmonwealth 6-5375, TWX; BS 1032, FAX; BSN
Representatives in principal cities
Export Office: 240 West 17th St., New York 11, N. Y.
Tel. CHelsea 3-5200, CABLE: TRILRUSH

CIRCLE 150 ON READER-SERVICE CARD



NEW!



...for High Vacuum Use... Teflon* Needle Valves** With "O" Ring Seals

Now . . . obtain flow control of highly corrosive fluids, under high vacuum! Manostat's new teflon needle valve both provides delicate flow control and utilizes rubber "O" rings, not in contact with the fluid, for high vacuum isolation from the surroundings without contamination!

In this newly designed valve, fluids touch only acid-and-alkali-resistant heavy wall pyrex brand glass connecting tubes, teflon valve body, and diamonite*** (sintered form of synthetic ruby) needle. All plastic parts not in contact with fluid are polypropylene — both corrosion resistant and able to withstand autoclaving temperatures. Result: no breakage, no contamination, dependable flow control!

PRICE LIST

Cat. No. NV1000—Teflon Needle Valve ready for use with directions but no glass parts. **6.95**

Cat. No. NV1200—Glass connecting tube. 80mm. long..... **.60**

Cat. No. VB2000—Delivery tip..... **.70**

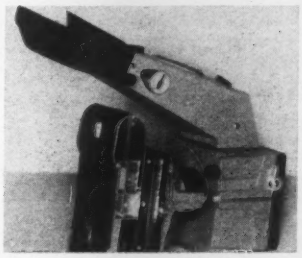
See Your Local Laboratory Supply Dealer

MANOSTAT Corporation
26 N. Moore St., New York 13, N.Y.

*DuPont trade name for polytetrafluorethylene **Patent applied for. ***Trade name for sintered corundum

CIRCLE 151 ON READER-SERVICE CARD

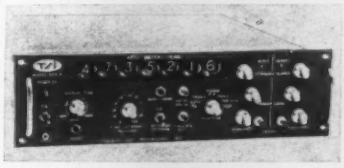
OSCILLOSCOPE TRACE CAMERA



New C-12 Camera for undistorted, direct recording of oscilloscope traces, uses sliding back (horizontal or vertical), 8 interchangeable lenses in varying object-to-image ratios and max aperture to f/1.5. Features one-hand portability, lift-on mounting, swing-away hinging, etc.—*Tektronix, Inc., Box* 500, *Beaverton, Ore.*

CIRCLE 314 ON READER-SERVICE CARD

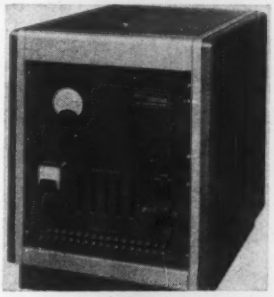
10-MC COUNTER-TIMER



New Model 365, 10-Mc Counter-Timer totalizes random events over any of 9 time intervals from 0.1 μsec to 100 sec, and any multiple of 10 sec (extended time base); straight counts with capacity of 9,999,999; frequency, from 10^{-7} to 10 sec; period measurements from 0.1 μsec to 10^{8} sec. Over-all stability of 5 parts in 10^{8} per week.—*Transistor Specialties, Inc., Terminal Dr., Plainview, L. I., N. Y.*

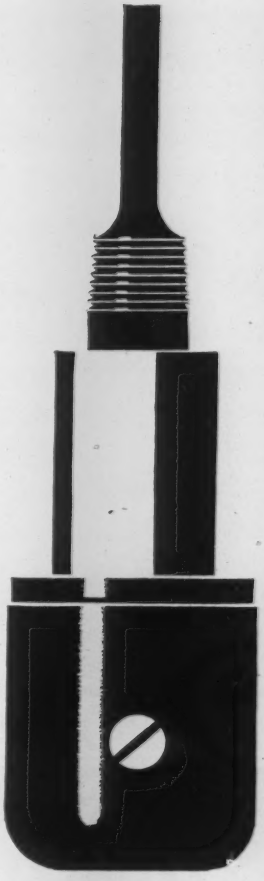
CIRCLE 315 ON READER-SERVICE CARD

PARTICLE SIZE ANALYZER



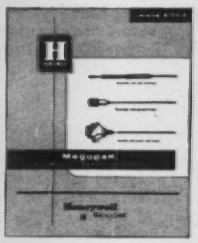
New Model PC200A Royco Particle Counter monitors atmospheres of clean rooms, etc., displays (on decade counters) numbers of particles present in 15 sub-ranges of sizes from 0.32 to 8.0 microns dia, or records on digital tape and/or strip-chart recorder. Automatic programming permits 0.3, 1, 3, or 10 minutes of monitoring on any or all sub-ranges in sequence. —*Royco Instruments Inc., 440 Olive St., Palo Alto, Calif.*

CIRCLE 316 ON READER-SERVICE CARD



MegopaK
THERMOCOUPLES

Honeywell's new line of hard-pack, small-diameter, mineral-insulated thermocouples. Available as bulk material (combination of wires, insulation and sheath); elements (with measuring junction); and as complete assemblies (with terminations and mounting attachments). From this one dependable source come thousands of other accessories to make your instruments perform at their very best.



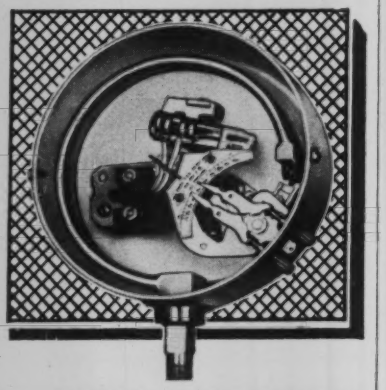
Get details from your Honeywell field engineer, or write today for Catalog G100-4.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Honeywell
First in Control
SINCE 1885

CIRCLE 152 ON READER-SERVICE CARD

A NEW ADDITION to MERCOID PRESSURE CONTROLS



316 STAINLESS STEEL

Welded Bourdon Tube and Pressure Connection

Series D-41, 243, 541

316 stainless steel welded Bourdon tube. ¼" (316) stainless steel pressure connection. Nickel plated mechanism. Outside adjustments. Calibrated dial. Hermetically sealed mercury contact.

Operating ranges: 30" vac.-75 psig; 10-100 psig; 30-400 psig; 75-800 psig. and 100-1000 psig.—with varying differentials and electrical capacity to meet your application.

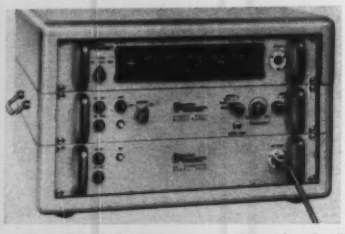
Three case styles: General Purpose NEMA 1; Weather-Proof NEMA 1A, 2, 3, 4; Explosion-Proof Class 1 Group C, & D; Class 2 Group E, F, G, NEMA 7, 9, 9A.

WRITE FOR BULLETIN 019

THE MERCOID CORPORATION
4211 Belmont Ave., Chicago 41, Ill.

CIRCLE 153 ON READER-SERVICE CARD

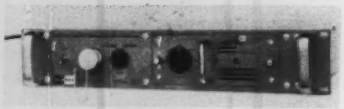
VOLTMETER/RATIOMETER



New Model 3510 transistorized, 5-digit, AC/DC Digital Voltmeter and Ratiometer features: a-c accuracy 0.1% and 2 digits; d-c, ±(0.01% and 1 digit); 0.1-mv sensitivity. Automatic d-c ranging and polarity; automatic, fixed or manual a-c ranging. Average balance time 2 sec (dc), 3 sec (ac). Improved 80-db filter measures mv of dc in presence of ac; twin bridge Zener diode reference.—*Electro Instruments, Inc., 3540 Aero Court, San Diego 11, Calif.*

CIRCLE 317 ON READER-SERVICE CARD

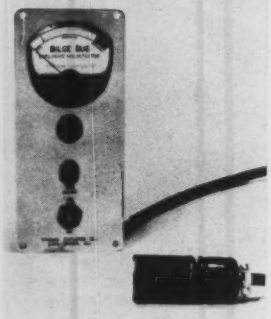
DIFF DC PREAMP



New 459B/N floating, narrowband, differential DC Preamplifier increases digital voltmeter sensitivity to 1 μv dc at gain setting of −100, isolates low level signals from noise and hum (common-mode rejection 180 db for dc, 130 db for 60 cps with up to 1000-ohm unbalance in either signal lead), exceeds 5 megohms input resistance, has accurate fixed gains.—*Kintel Div., Cohu Electronics, Inc., 5725 Kearny Villa Rd., Box 623, San Diego 12, Calif.*

CIRCLE 318 ON READER-SERVICE CARD

EXPLOSIVE GAS DETECTOR



New "Bilge Bug" consists of control and indicator panel, sensor unit and connecting cable, is supplied for 6 or 12 v dc, and draws 1.2 amp. Sensor unit is installed where combustible mixtures may collect—boats, storage areas, plants, etc.—*Industries, Inc., 75 Austin St., Newark 2, N. J.*

CIRCLE 319 ON READER-SERVICE CARD

IF

PRECISION MANUFACTURING IS YOUR REQUIREMENT

. . . then Boehme practical experience in the design and manufacture of mechanical, electrical and electronic products for automation and instrumentation can solve your most exacting demands. Learn more about Boehme's prompt, efficient, economical service and how readily it applies to your needs.

H. O. Boehme, Inc.

Designers and Manufacturers
Communication Equipment
Precision Electro-Mechanical
Apparatus Since 1917

915 Broadway
New York 10, N.Y.

HOB

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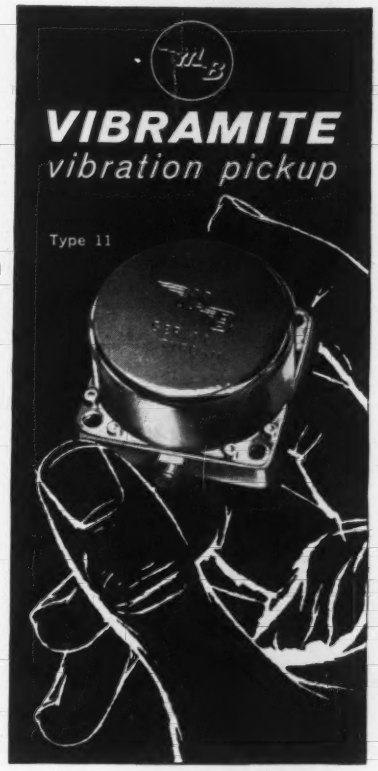


sensitive . . .
yet rugged
damped . . . *yet with flat response*

In fact, the new Vibramite pickup is the only available damped unit with a flat response curve over its entire operating range.

It is also small in size, light in weight . . . and can be mounted in any desired position without adjustment.

Models are available for varying temperature extremes and test frequency requirements.

Check these specifications:

Frequency range	20-2000 cps
Sensitivity	96.3 mv/in/sec. (Calibrated ±1% at 100 cps into 2 megohm load at 80°F)
Size	1″ x 1.42″
Weight	2.75 oz
Natural frequency	15 cps
Damping	Eddy current (nominal .65 of critical)
Acceleration output limit	50 g maximum (minimum limited only by recording equipment)
Max. shock without damage	1000 g

Complete technical details in Bulletin 112A. Write . . .

MB ELECTRONICS
A DIVISION OF TEXTRON ELECTRONICS, INC.
1103 State Street, New Haven 11, Conn.
CIRCLE 155 ON READER-SERVICE CARD

ATTITUDE SENSOR

New electronic mirroring Sensor positions orbiting satellites, uses 0.1-w power, has no rotating parts or bearings, requires no lubrication. Potential space life of 5-10 yr.—*International Telephone and Telegraph Corp., 67 Broad St., New York 4, N. Y.*

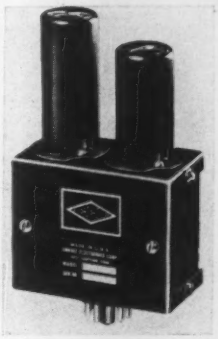
CIRCLE 320 ON READER-SERVICE CARD

POSITION TRANSDUCER

New Position Transducer for machine tool automation systems uses non-contact magnetic sensing heads. Senses shaft rotation (0.0001″ increments at position speeds up to 120 ipm, or 0.001″ increments at speeds of 200 ipm or more) and changes information to digital pulses which measure linear motion.—*Electronics Div., Rheem Manufacturing Co., 5200 W. 104 St., Los Angeles, Calif.*

CIRCLE 321 ON READER-SERVICE CARD

OPERATIONAL DC AMPLIFIER



New Model B/100/M high-gain plug-in Operational DC Amplifier for analog computers, system simulation, and control applications has inherent drift low enough not to require chopper stabilization. Output is 6 ma over range of ±100-v dc.—*Embree Electronics Corp., 993 Farmington Ave., West Hartford 7, Conn.*

CIRCLE 322 ON READER-SERVICE CARD

GIVE YOU
BETTER THAN
¼% ACCURACY
. . . DESIGNED-IN, CONSTANT, GUARANTEED

Greibach-patented Bifilar no-friction movement and weightless light beam pointer use no pivots, no jewels, no hairsprings, no amplifiers. Greibach meters start with near-perfect accuracy. Accuracy is ***unaffected even by overloads of 100,000%*** (to 125,000,000% in some cases). Rugged, shock-proof design cradles the coil; withstands up to 500 G's. There's nothing to wear, vary or age with use, so accuracy remains high over long periods. Most meters leave our plant with measured accuracy of better than 1/10%.

OTHER EXCLUSIVE GREIBACH PRECISION METER FEATURES:

- Sensitivity to 0.2 μamp. full scale
- Resistance to 1/300th of conventional meters
- Energy drain as low as 4 x 10^{-19} watt
- No parallax errors from any reading angle
- Multpile Ranges—up to 23 in one meter.

The secret of Super-Precision Performance is in this cartridge, containing unique Bifilar Suspension.

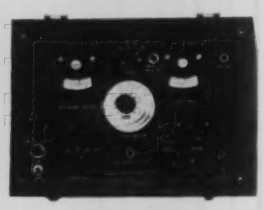
For full details on the thousands of range-combinations available, write, wire or phone today for detailed 20-page catalog.

GREIBACH INSTRUMENTS CORPORATION
331 North Ave., New Rochelle, N. Y.
Phone: NEw Rochelle 3-7900
Box 2900
CIRCLE 156 ON READER-SERVICE CARD

TEST EQUIPMENT
BY...tensor

PORTABLE AC-DC REFERENCE SOURCE

MODEL 5890 $495



Here is a completely self contained standard for meter calibration. Accuracy is held to .25% of set voltage. Supplies are regulated and one watt of power is available from 0 to 100 volts.

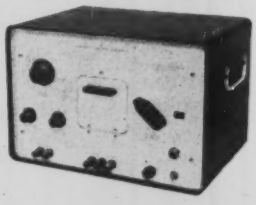
INCREMENTAL ANALYZER

MODEL 5880 $250

This general purpose input adapter for high impedence recorders is used to allow the display of any voltage, current, resistance or temperature measurable on the units VOM. Increments of any part of the range may be expanded to full scale readout on a recorder or sensitive DC millivoltmeter.

ARBITRARY FUNCTION GENERATOR

MODEL 5846 $495



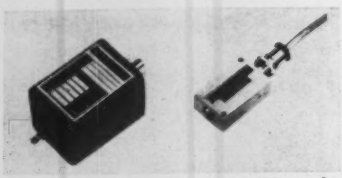
Covering the frequency range of .001 to 10 cycles per second, waveforms are programmed by shaped cams. In addition to the selected function, a square wave at the same frequency is also produced. Function derived can modulate a 60 cycle or other frequency carrier to yield a suppressed-carrier waveform useful in servo testing.

For detailed information, send for data sheets.

tensor
ELECTRIC DEVELOPMENT CO., INC.
1873 Eastern Parkway Brooklyn 33, New York
HY 5-9200

See us at Booth 3945 at the IRE Show
CIRCLE 157 ON READER-SERVICE CARD

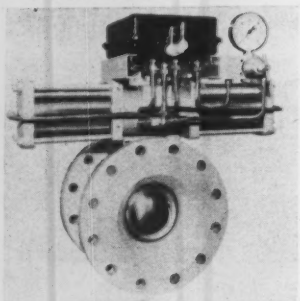
PHOTOELECTRIC CONTROLLER



New PE-601 solid-state Photoelectric Controller consists of transistor amplifier and power supply packaged in plug-in unit (2" x 2" x 1½"). Power consumption less than 3 w total. Counting rate to 2000 cpm. Output relay DPDT, 5-amp contact rating. Can be light- or dark-operated.—*Syracuse Electronics Corp., Box 566, Syracuse 1, N. Y.*

CIRCLE 323 ON READER-SERVICE CARD

POSITIONING RELAY



New Bailey Positioning Relay used with Jamesbury Ball Valve and pneumatic operator automatically controls flow of media through pipe lines. Relay, serving as throttling device, positions valve to desired rate of flow from 0° to 90°; translates signals from controller to pneumatic impulse that acts upon valve.—*Jamesbury Corp., 78 New St., Worcester, Mass.*

CIRCLE 324 ON READER-SERVICE CARD

PRIMARY RESISTANCE OVEN

New Model PRO-106 Primary Standard Resistance Oven accurate to 0.0008% has six decade standards to cover 100 ohms to 10 megohms (accuracy and stability derated to 0.0015% at 10 megohms), temp coefficient less than 0.05 ppm/°C from 15° to 35°C.—*Julie Research Labs., 603 W. 130 St., New York 27, N. Y.*

CIRCLE 325 ON READER-SERVICE CARD

Waugh
TURBINE FLOW METERS
for high accuracy
CONTROLLING TOTALIZING and BLENDING

Waugh Turbine Flow Meters provide outstanding accuracy and reliability in fluid processes where blending in precise ratios, batch control, or flow rate control is required. Turbine flow meters have a **linear** output which simplifies totalizing, and maintains full accuracy in pulsating flow conditions. Accuracy is ½% of the flow rate over flow ranges as high as 20:1, and even better over narrow ranges.

Control devices designed for use with Waugh Turbine Flow Meters include solid state counters, totalizers, controllers, and complete digital blending systems to blend simultaneously as many as 20 different components.

Waugh Turbine Flow Meters occupy only a fraction of the space required for other flow meters of comparable accuracy. For example, a 4 inch Waugh Turbine Flow Meter, having an overall length of 10 inches, and no larger in diameter than the pipe itself, will measure flows from 60 to 1250 GPM, with an absolute accuracy of ½%, and a repeatability of better than 0.1%. A complete flow control loop includes only three elements: a flow meter, a controller, and a control valve.

FOR COMPLETE INFORMATION REQUEST WAUGH BULLETIN 114

Waugh *Engineering Representatives in Principal Cities*

WAUGH ENGINEERING COMPANY
7842 Burnet Avenue, Van Nuys, Calif.

CIRCLE 158 ON READER-SERVICE CARD

Test your BUILDING BLOCK IQ

How complete is your knowledge of digital system building blocks? Test yourself with these five questions:

1 Q. Who manufactures the highest speed digital system building blocks available today?

A. _____

2 Q. Which manufacturer utilizes a standard clamp voltage to absolutely insure the exact same voltage levels in all circuits?

A. _____

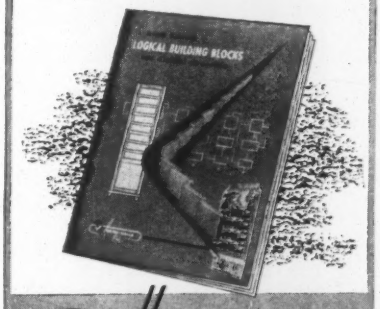
3 Q. Whose logic circuits have been evaluated time after time by independent organizations and consistently proven superior electrically to all other building blocks in use today?

A. _____

4 Q. Which manufacturer's package designs have been similarly evaluated and consistently proven superior to all other designs — in ruggedness, compactness, appearance and overall ease of handling?

A. _____

If your answer to every question was Harvey-Wells Electronics, your building block IQ is perfect . . . If not, write today for our new technical brochure plus a complete set of specification bulletins.



Harvey-WELLS ELECTRONICS INC.

14 HURON DRIVE, NATICK, MASS.

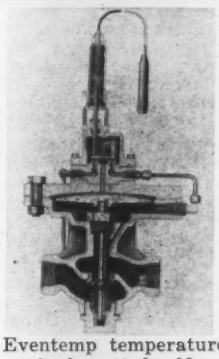
CIRCLE 159 ON READER-SERVICE CARD

PREDETERMINING COUNTER

New CE-901 electrically actuated predetermining Counter counts at speeds to 1000 cpm (2- to 5-digit models available), is quickly preset. Control Relay has SPDT contacts rated 4 amp at 115-v ac.—*PIC Automation Controls Div., General Controls Co., 8062B McCormick Blvd., Skokie, Ill.*

CIRCLE 326 ON READER-SERVICE CARD

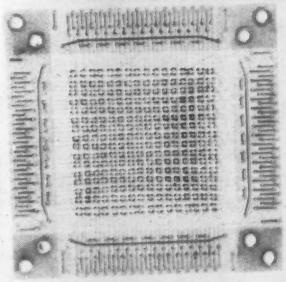
TEMP REGULATOR



New Eventemp temperature regulators are single-seated self-contained units, diaphragm-actuated, with lever-type internal pilot. Units have pressurized, self-cleaning, friction-free teflon stem seal and tight closing, positive-seating main valve. Trim parts can be inspected or renewed with body in pipe line. Cast iron or bronze bodies.—*Leslie Co., 122 Delafield Ave., Lyndhurst, N. J.*

CIRCLE 327 ON READER-SERVICE CARD

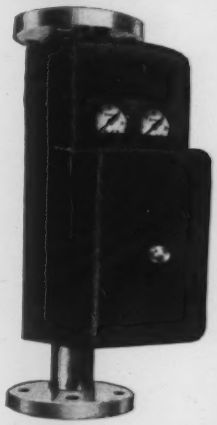
MEMORY FRAMES



New Memory Frames for memory systems in computers achieve low cost with prefabricated printed circuit strips that minimize assembly time. Four sizes of strips (32-, 48-, 64-, 96-wire) allow ten frame configurations. —*Lockheed Electronics Co., Avionics and Industrial Products Div., 6201 E. Randolph St., Los Angeles 22, Calif.*

CIRCLE 328 ON READER-SERVICE CARD

THE FLOW GOES STRAIGHT-THRU



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no pockets, no elbows to gum up the works!

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You can use it for slurries, still bottoms, Bunker oils, pthalic anhydrides, tall-oil compounds—virtually any 'problem' fluid.

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Above all, you can use it with absolute confidence.

Have a look at the transmitter's unique magnetic float-position converter, and you'll see why.

Design Secification Sheet DS-361 gives details. Write for a copy.

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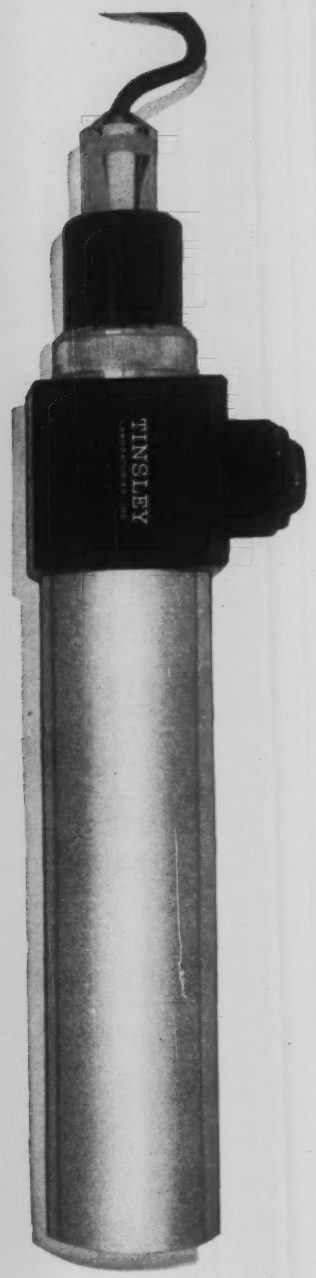
HATFIELD • PENNSYLVANIA
SA2115

CIRCLE 160 ON READER-SERVICE CARD



Why pay for an expensive alignment telescope when a Tinsley Autocollimator may meet your requirements for hundreds of dollars less? The Tinsley Autocollimator is easily capable of reading precise angles to ¼ minute accuracy. 20 power. Interchangeable light source and eyepiece for viewing from end or side. Fits standard fixtures. Economical and dependably accurate. Write for price and information.

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LABORATORIES, INC.
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CIRCLE 161 ON READER-SERVICE CARD

ICS NEW LITERATURE

MESSAGE DISPLAYER. 4-page Bulletin 1003 explains operation and features of Type SD-11 miniature spheriicular optic displays.—Burroughs Corp., Electronic Tube Div., Plainfield, N. J.
CIRCLE 336 ON READER-SERVICE CARD

DIGITAL MODULES. 12-page Catalog S describes Series S-PACS for dc to 1 Mc operation.—Computer Control Co., Inc., 983 Concord St., Framingham, Mass.
CIRCLE 337 ON READER-SERVICE CARD

MONITOR ALARM. 4-page brochure describes Signal Sentry monitor alarm system accurate to 0.1% for 30 stations, portable, self-checking, 6-months maintenance-free operation.—Communications Control Corp., 14707 Keswick St., Van Nuys, Calif.
CIRCLE 338 ON READER-SERVICE CARD

POWER SUPPLIES. 8-page Catalog 120 details solid state power supplies, including miniaturized power packs, solid state inverters, converters, etc.—Electronic Research Associates, Inc., 67 Factory Place, Cedar Grove, N. J.
CIRCLE 339 ON READER-SERVICE CARD

CODE CONVERTER for punched tape is featured in 6-page booklet.—Friden, Inc., 1 Leighton Ave., Rochester 2, N. Y.
CIRCLE 340 ON READER-SERVICE CARD

TAPE TRANSMITTER-RECEIVER. 10-page booklet describes Friden Dual Teledata Tape Transmitter-Receiver designed to transmit single continuous tape at twice speed of similar standard model.—Friden, Inc., 1 Leighton Ave., Rochester 2, N. Y.
CIRCLE 341 ON READER-SERVICE CARD

TRANSFORMERS. 2-page data sheet describes and diagrams Series 7100 electrostatically and magnetically shielded instrument transformers for chopper, a-c transducer and differential input.—James Electronics Inc., 4050 N. Rockwell St., Chicago 18, Ill.
CIRCLE 342 ON READER-SERVICE CARD

3" PORTABLE OSCILLOSCOPES. 7 types, are described in 16-page booklet.—Tektronix, Inc., Box 500, Beaverton, Ore.
CIRCLE 343 ON READER-SERVICE CARD

RECORDING OSCILLOGRAPH. Type 5-123, provides visible records up to 60 times faster than other printout processes, is described in 8-page Bulletin 1623.—Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.
CIRCLE 344 ON READER-SERVICE CARD

PORTABLE THERMOCOUPLE calibration stand and thermocouple reference junction compensator are described in 2-page Catalog Supplement 206.—Harco Laboratories Inc., 77 Olive St., New Haven, Conn.
CIRCLE 345 ON READER-SERVICE CARD

VOLTAGE DIGITIZERS. 4-page data sheets on V16-AD, VR 12-AD, VR 12-AB voltage digitizers contain performance specs, functional block diagrams, and logic descriptions. Six-page "Voldicon" catalog describes 8 basic types in voltage digitizer line.—Adage Inc., 292 Main St., Cambridge 42, Mass.
CIRCLE 346 ON READER-SERVICE CARD

PHYSICS RESEARCH LABS' test facilities are described in 4-page brochure.—Physics Research Laboratories, Inc., Box 555, Hempstead, N. Y.
CIRCLE 347 ON READER-SERVICE CARD

DIGITAL MODULES. 6-page folder describes 5000 Series of Digital Test Equipment and 6000 Series of 10-Mc Building Blocks.—Digital Equipment Corp., 146 Main St., Maynard, Mass.
CIRCLE 348 ON READER-SERVICE CARD

PLOTTERS. 8-page Bulletin PG-100 describes Gilmore Standard, High Speed, and Extra High Speed Strain Gage Plotters; Modular Plotter; Segmental Recorder and Scanner Plotter.—Gilmore Industries, Inc., 13015 Woodland Ave., Cleveland 20, Ohio.
CIRCLE 349 ON READER-SERVICE CARD

PLOTTING BOARDS. 5-page Form 80-392 describes transistorized XY plotting boards, single and dual arm, with electroluminescent panels for backlighting.—Computer Systems, Inc., Culver Rd., Monmouth Junction, N. J.
CIRCLE 350 ON READER-SERVICE CARD

VOLTMETER. 2-page Bulletin GEZ-3254 describes high accuracy, Type DB-18 expanded scale voltmeter.—General Electric Co., Schenectady 5, N. Y.
CIRCLE 351 ON READER-SERVICE CARD

VOLTAGE DIGITIZERS. Six 4-page data sheets describe with diagrams, specifications, and applications, Voldicons, Types V9-AB, VR9-AB, VR10-AB, VR12-AB, V12-AD, and V16-AD.—Adage, Inc., 292 Main St., Cambridge 42, Mass.
CIRCLE 352 ON READER-SERVICE CARD

LAB FURNITURE. Wall chart covers results of a laboratory furniture-market research report "Suggested Built-In Instruments and Equipment of Laboratory Furniture—including Certain Specific Finish Requirements."—Laboratory Equipment Section, Scientific Apparatus Makers Association, 20 N. Wacker Dr., Chicago 6, Ill.
CIRCLE 353 ON READER-SERVICE CARD

BALLISTIC FLARER. 4-page folder describes cartridge-actuated tool that flares heavy wall stainless steel tubing.—Parker Fittings & Hose Div., Parker-Hannifin Corp., 17325 Euclid Ave., Cleveland 12, Ohio.
CIRCLE 354 ON READER-SERVICE CARD

POSITION TRANSMITTER. 2-page Specification sheet P99-10 describes operation of position transmitter with characteristic curves of percent travel versus percent signal.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.
CIRCLE 355 ON READER-SERVICE CARD

MINIATURE FILTER ASSEMBLY. 4-page Bulletin 600 provides information on miniature in-line filter assembly for caustic and/or corrosive liquids or gases.—Dumont Engineering Corp., 1401 Freeman Ave., Long Beach, Calif.
CIRCLE 356 ON READER-SERVICE CARD

PERSPECTIVE CIRCLES. 2-page flyer describes underlay guides available to draw perspective circles from 5° to 70°.—Graphicraft, Box 509, Westport, Conn.
CIRCLE 357 ON READER-SERVICE CARD

ICS NEW LITERATURE

POWER CENTERS. 12-page Bulletin GEA-7080 gives data on custom-built Cabinetrol Centers.—General Electric Co., Schenectady 5, N. Y.

CIRCLE 358 ON READER-SERVICE CARD

CONTROL FOR KILNS. 8-page Bulletin 600 describes metering and control instruments for rotary kilns and associated equipment.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

CIRCLE 359 ON READER-SERVICE CARD

REGULATORS & CONTROL VALVES. 46-page manual illustrates and describes regulators, thermometers, valves, and accessories for steam and water service with application diagrams.—Powers Regulator Co., 3400 Oakton St., Skokie, Ill.

CIRCLE 360 ON READER-SERVICE CARD

MAGNETIC FLOWMETER SYSTEM. 8-page Specification 10D1410B describes metering system comprised of a magnetic flowmeter and indicator/recorder which measures fluids with conductivities as low as 0.1 micromhos/cm.—Fischer & Porter Co., 743 Jacksonville Rd., Warminster, Penna.

CIRCLE 361 ON READER-SERVICE CARD

TURBINE FLOWMETER. 4-page Bulletin 10C1505 describes and specifies propeller-type flowmeter that transduces gas velocity to a millivolt signal, the frequency of which is proportional to flow rate.—Fischer & Porter Co., 739 Jacksonville Rd., Warminster, Penna.

CIRCLE 362 ON READER-SERVICE CARD

METERING PUMPS. 4-page brochure "Profits Down the Drain" points up losses from stuffing-box leakage and methods of overcoming these problems by metering units with leak-proof design.—Process Equipment Div., Lapp Insulator Co., 124 Hall St., LeRoy, N. Y.

CIRCLE 363 ON READER-SERVICE CARD

THERMOCOUPLE PYROMETERS. 4-page Bulletin 8-60 fully describes 3 types of pyrometer-millivoltmeters for measuring temperatures with thermocouples. Lists scale ranges and selection of thermocouple types.—Lewis Engineering Co., Naugatuck, Conn.

CIRCLE 364 ON READER-SERVICE CARD

AIR TRANSMITTER. 2-page Bulletin 86.20 describes Air Transmitter, Model 86-01, which produces pneumatic pressures proportional to the speed of rotation of a primary unit.—B-I-F Industries, 345 Harris Ave., Providence, R. I.

CIRCLE 365 ON READER-SERVICE CARD

RESET ACROTIMER. 4-page folder gives detailed information on External Clutch Reset Timer, opening or closing switches after an adjustable period of time.—Haydon Div., General Time Corp., 245 East Elm St., Torrington, Conn.

CIRCLE 366 ON READER-SERVICE CARD

SAND FILTER CONTROL. 4-page Bulletin 450 describes operation of sand filter controls in automatic plants.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

CIRCLE 367 ON READER-SERVICE CARD

RECORDING INSTRUMENTS. 4-page brochure, Form 960, illustrates and describes features of recorders for electrical units, events, speed, position, motion, pressure, vacuum, etc.—Esterline-Angus Co., Box 596, Indianapolis, Ind.

CIRCLE 368 ON READER-SERVICE CARD

DIGITAL VOLTMETERS. 6-page folder describes important differences in digital voltmeters and points out NLS exclusive features.—Non-Linear Systems, Inc., Del Mar, Calif.

CIRCLE 369 ON READER-SERVICE CARD

R-F VOLTMETERS. 2-page Bulletin 800 describes and specifies 100-megacycle laboratory-standard voltmeter.—Rawson Electrical Instrument Co., Inc., 110 Potter St., Cambridge 42, Mass.

CIRCLE 370 ON READER-SERVICE CARD

SWITCHBOARDS. 24-page Brochure GED-4239 gives information on secondary-control switchboards. Features, dimensions, components, and the basic-circuit construction are detailed.—General Electric Co., Schenectady 5, N. Y.

CIRCLE 371 ON READER-SERVICE CARD

MAGNETIC AMPLIFIERS. 2-page Bulletin 1316-3 describes Mega-power high capacity magnetic amplifiers available in seven sizes, from 75 hp to 400 hp.—Vickers Incorporated, Electric Products Div., 1815 Locust St., St. Louis 3, Mo.

CIRCLE 372 ON READER-SERVICE CARD

INSTRUMENT VACUUM TUBES. 8-page Bulletin PA-39, describes characteristics and uses for tubes which are manufactured specifically for instrument manufacturers.—CBS Electronics, 100 Endicott St., Danvers, Mass.

CIRCLE 373 ON READER-SERVICE CARD

INDUSTRIAL HUMIDIFICATION. 2-page bulletin on Humidification for Data Processing covers the importance of controlling both temperature and relative humidity to retain accuracy of computing machinery.—Walton Labs., Inc., Irvington 11, N. J.

CIRCLE 374 ON READER-SERVICE CARD

D/A CONVERTERS. 3-page data sheet covers specs and applications of binary-type, solid-state digital to analog converter.—Dynamic System Electronics Corp., 2001 N. Scottsdale Rd., Scottsdale, Ariz.

CIRCLE 375 ON READER-SERVICE CARD

LOW-COST COMPUTER. 4-page brochure describes new Recomp III computer and lists its advantages.—Autonetics, a Div. of North American Aviation, Inc., 9150 E. Imperial Highway, Downey, Calif.

CIRCLE 376 ON READER-SERVICE CARD

A GREAT NAME IN THERMOMETERS

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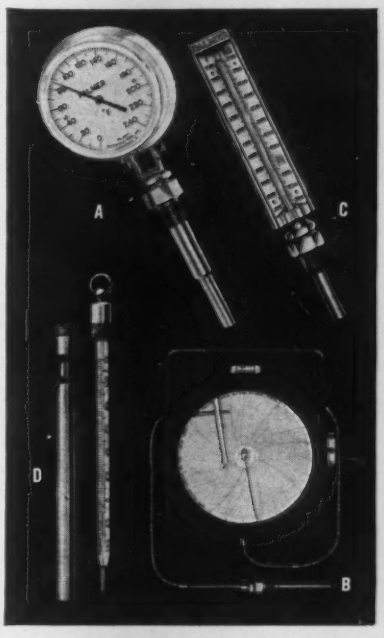
Mercury Actuated
Temperature Indicating Instruments



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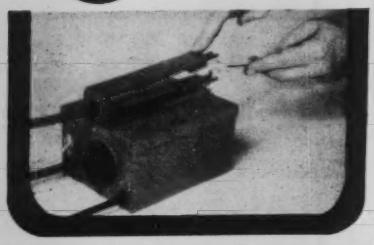

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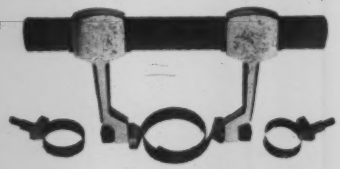

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Immediate Shipment of Rebuilt Pyrometer Equipment From Stock
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3 BASIC UNITS FOR CONTINUOUS INTEGRATION WITH A VARIETY OF INPUTS

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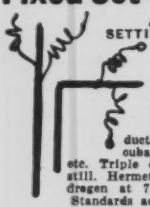
Fixed Set Thermostats



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SETTING RANGE: −35°C to 370°C
SET SENSITIVITY: ±.01°C

Guaranteed sensitivity . . . year-in, year-out reliability . . . accurate control of temperature in ovens, electronic equipment, baths, ducts, freezers, fire alarms, incubators, analytic instruments, etc. Triple distilled mercury; filled at still. Hermetically sealed with dry hydrogen at 75 psi. Calibrated to Bur. Standards accuracy. Priced 10% to 15% lower than competitive lines.

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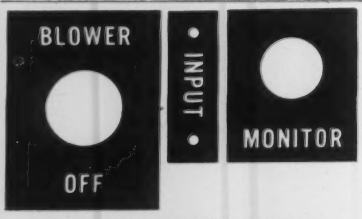

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PYROTEL gives meter indication, recording output and relay control. It will monitor, signal or control extrusion, hot forming, web drying, forging, heat treating, melting or hardening processes. Fast, non-corroding and dependable operation proved by leading manufacturers.

Models are available for all temperature ranges, from 140° F. upwards. Versatile, accurate and dependable. Write for information, recommendation and quotation.
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SAVE TIME and MONEY

Beam lengths from 7" to 78½" one piece anodized aluminum. Coursers available in Aluminum, Nylon, or attractive Plastic. Sets available, individually priced from $3.45 or made up to individual requirements. (15% quantity discount on 3 or more sets)
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Model HT-12 Four-Range Tachometer

Centrifugal tachometer that measures revolutions per minute and surface speeds.

TOTAL RANGE: 90-12,000 RPM
1st — 90-360 RPM
2nd — 300-1200 RPM
3rd — 900-3600 RPM
4th — 3000-12000 RPM
Feet per minute—one half the dial reading with use of 6" disc wheel.

Advantages: Accuracy—±0.5% • Stop button feature • Instantaneous readings • 3" easy to read dial • Light—approx. 14 oz.

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SMITHS TACHOMETERS
For Precise and Rapid Measurements of
SHAFT SPEEDS CUTTING SPEEDS SURFACE SPEEDS

- **Magnetic Design** Steady readings accurate to ±0.5%
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PERMANENT MAGNET
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seeks qualified Manufacturer Representatives in the Environmental Test Field for all territories except New England."

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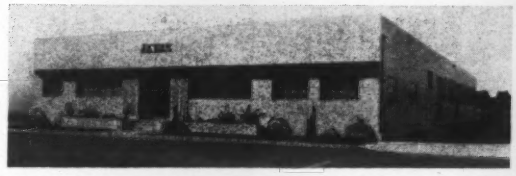
ICS INDUSTRY NEWS

CONOFLOW CORP. has elected *J. Robert Simpson*, now general sales manager, a vice president.

J. R. SIMPSON

W. FALSTROM

CUBIC CORP. has elected *William Falstrom* as president of its newly organized subsidiary **TEMEC**, Inc.



LOUIS LEVIN & SON, INC. have moved into new larger quarters in Culver City.

TELECHROME MFG. CORP. announces that *Solomon Hudes* has joined the corporation as vice president in charge of engineering.

S. HUDES

W. VANNAH

FOXBORO COMPANY announces appointment of *William E. Vannah*, former chief editor of Control Engineering, as associate for advanced engineering.

MINNEAPOLIS-HONEYWELL has changed the name of its *Marion Instrument Division* to *Precision Meter Division.*

MESUCORA, the International Exhibition devoted to measurement, control, regulation, and automation will take place in Paris, France, May 9-17, 1961 at the Centre National des Industries et des Techniques. Exhibition area will be 380,000 sq ft. Exhibitors from 12 European countries and the U.S.A. will show their wares. For information address Secretariat General, 40 Rue du Colisee, Paris (8°), France.

SERVOMECHANISMS INC. has been appointed the exclusive repair, overhaul, and certification agency (in the 11 Western states) for *Hass Instrument Co.*, manufacturers of barometers and manometers. Special facilities and rigid procedures have been set up to maintain the high standards necessary in the calibration of its precision electromechanical pressure measuring systems.

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when it MELTS you know the *temperature!*

NEW *Markal* THERMOMELT TEMPERATURE INDICATORS

With Handy Adjustable Holder

The easy modern way to determine exact working temperatures!

Just mark or stroke the surface with THERMOMELT . . . when it reaches the desired temperature, the mark liquefies. There's no guesswork, no wasted time or material . . . THERMOMELT is the quick, precise way to determine heating temperatures. Accurate to within ±1%.

A Stik For Every Temperature from 113° F. to 2000° F.

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ALSO AVAILABLE IN LIQUIDS AND PELLETS for inaccessible or hard-to-measure applications. Wide range of temperatures.

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● ELIMINATE DELAYS!

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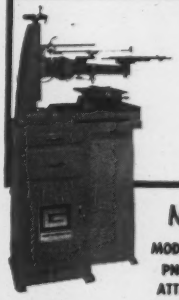

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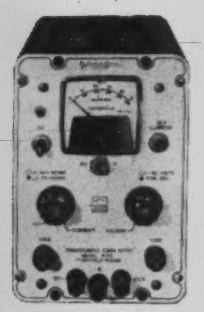

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